Olmsted Brothers.

The Climate and Weather of San Diego, California

The Bay of San Diego from Point Loma. From a painting by Fries

The Climate and Weather of San Diego California

Prepared under the direction of

WILLIS L. MOORE

Chief United States Weather Bureau

BY

FORD A. CARPENTER

Local Forecaster

ILLUSTRATED WITH PHOTOGRAPHS AND CHARTS BY THE AUTHOR AND OTHERS

The term climate, in its broadest sense, implies all the changes in the atmosphere which sensibly affect one's physical condition. —HUMBOLDT

PUBLISHED BY THE
SAN DIEGO CHAMBER OF COMMERCE
1913

J. Horace McFarland Company
Mt. Pleasant Press
Harrisburg, Pennsylvania

Captain Juan Rodriguez Cabrillo entered San Diego Bay and made the first meteorological observation in what is now San Diego, California, during September, 1542.

Report: Climate and Weather
of San Diego.

WLM

UNITED STATES DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,
OFFICE OF THE CHIEF,
WASHINGTON, D. C. August 14, 1912.

Mr. Ford A. Carpenter,

Local Forecaster, Weather Bureau,

Los Angeles, Cal.

Sir:

Replying to your letter of June 29, 1912: I find that your report on the climate and weather of San Diego, Cal., has been carefully prepared in accordance with the meteorological records, and I therefore approve of its publication.

Such fruitful and conscientious service as you rendered while official in charge of the local office of the Weather Bureau at San Diego is helpful to the weather service and is appreciated by this Office.

Very respectfully,

Willis L. Moore

Chief U.S.Weather Bureau.

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CHAPTER I

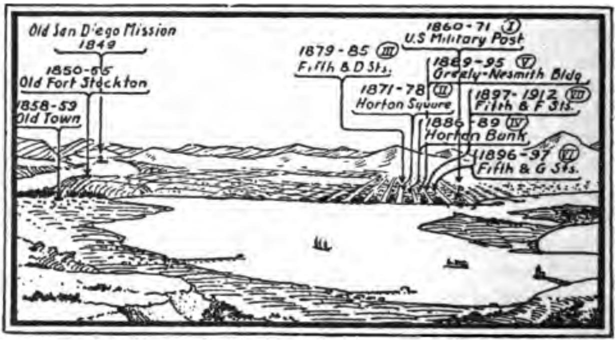
HISTORY OF WEATHER OBSERVATIONS IN SAN DIEGO

SAN DIEGO has had an uninterrupted governmental meteorological record since July 1, 1849. For the first twenty years the work was under the supervision of the Medical Corps of the Army.

It would be interesting to know the name of the hospital steward who began the unbroken record of San Diego's temperature and rainfall observations on that distant July day. The thermometers and rain-gage were placed in the shadow of the walls of the old San Diego mission, which were standing, though even then in a dilapidated condition. The United States troops used the old mission as headquarters for a year; afterwards the military post was transferred to the vicinity of the old Mexican presidio at what is now Old Town. It speaks well for the discipline of the Medical Corps of the Army that meteorological observations (which, in the early days, were part of the post surgeon's duties) were continued, without a break, until the instruments and records were transferred to the Signal Service on November 1, 1871. Between 1856 and this transfer the location of the instruments was changed twice—

both times nearer the present site of San Diego. During the past half-century the meteorological instruments have been located within a radius of half a mile. The weather observations in new San Diego were first made at the old H Street barracks; fifteen years later, when the Signal Service assumed control, the office was established in Horton Square, later changing to the site of the present Union Building; then to the corner of Fifth and D Streets, and again to Fifth and F Streets, where the weather office is at present located. When the new Federal Building is finished in the early part of the year 1913, the Weather Bureau will have completed its half-mile circle of wanderings back to its starting-place at the old military reservation.

The following sketch-map of the San Diego Bay region indicates the various locations of the meteorological station from 1849 to date.



San Diego Bay Region, showing location of the United States Weather-Observing Stations since July, 1849

NON-INSTRUMENTAL WEATHER OBSERVATIONS BEGAN IN 1542

The non-instrumental observations of San Diego weather occur in the writings of many famous men during the past 370 years: Cabrillo, in 1542; Viscaino, in 1602; Serra, in 1769; Dana, in 1835; Agassiz, in 1872; and Greely, in 1888, have contributed to its meteorology. The first record we have is from Juan Rodriguez Cabrillo, the discoverer of San Diego Bay, who entered in his ship's log in September, 1542:

> *A very great gale blew from the southwest; the port being good, we felt nothing.*

Sixty years later Sebastian Viscaino surveyed the harbor, and made the first observations of any considerable value. Father Junipero Serra, in July, 1769, established at San Diego the first mission in California. In his letters home he mentioned the similarity of this climate to that of his beloved Spain. Sixty years later Richard Henry Dana visited San Diego, and, in his "Two Years Before the Mast," gave an account of the early days in this region that will forever remain a classic. In commenting on the storm-winds of California, Dana, in 1835, said:

> *This wind [the southeaster] is the bane of the coast of California. Between the months of November and April, including a part of each (which is the rainy season in this latitude), you are never safe from it; and accordingly, in the ports which are open to it, vessels are obliged during these months to lie at anchor at a distance of three miles from the shore, with slip-ropes on their cables, ready to slip and go to sea at a moment's warning. The only*

ports that are safe from this wind are San Francisco and Monterey in the north and San Diego in the south.

Some are still living in San Diego today who heard Alexander Agassiz, in 1872, give his impressions of his visits to San Diego in the following words:

> *In enumerating the peculiar advantages of San Diego, there seems to be one which is of very great importance. Perhaps, as a scientific man, I may lay more stress upon it than is necessary, but I hardly think it possible; I have seen many parts of the world, and have made some study of this subject. It is the question of the climate of your latitude that I refer to. You have a great capital in your climate. It will be worth millions to you. This is one of the favored spots of the earth, and people will come to you from all quarters to live in your genial and healthful climate, a climate that has no equal.*

To bring this chronological history up to the close of the nineteenth century, the following quotation is made from a former resident, General A. W. Greely. When, as Chief Signal Officer of the Army, he was at the head of the United States Weather Service, he contributed a paper on the climates of the United States. In this article he said:

> *The American public is familiar on all sides with elaborate and detailed statements of the weather at a thousand and one resorts. If we may believe all we read in such reports, the temperature never reaches the eighties, the sky is flecked with just enough of cloud to perfect the landscape, the breezes are always balmy, and the nights ever cool. There is possibly one place in the United States where such conditions obtain—a bit of country about forty miles square, at the extreme southwestern part of the United States, in which San Diego, California, is located.*

CHAPTER II

THE VELO CLOUD

THE challenge, "We all know the winters are warm in San Diego, therefore the summers must be hot," constitutes the most common misunderstanding of San Diego's cool summers. The fact that there is less than one hour per year above 90 degrees is not easy to explain, until we remember the old Mexican phrase, *El velo de la luz*, "The veil that hides the light." This is a folk-lore expression, originating not only before the Gringo came, but, doubtless, long before the coming of the old Spanish conquistadors. The better-known English term, "high fog," has, in common with most words of our language, a double meaning, and it is misleading to a non-resident. It is not fog in the generally accepted meaning, for this "light-veil" is neither cold nor excessively moisture-laden. Neither is it high, for its altitude is less than a thousand feet.

To one who has spent a few weeks of spring, summer, or fall in southern California, the picturesque description of the musical Spanish *el velo* is quickly recognized as both expressive and truthful. A noted English traveler gave his views on the "*velo*" cloud in a communication to the San Diego "Union." He said:

> *I am glad that the old Spanish word "velo" is brought to light. The velo cloud is so expressive of the lovely diaphanous cloud that, of a midsummer's morning, shades*

San Diego's brilliant sun until such time as the "veil" is swept aside by the ocean breeze, whose cooling breath renders it no longer necessary for a perfect day by the "Harbor of the Sun." I have always felt sure that those fine old Spaniards never damned so good a thing by such an abusive and misleading term as "high fog." As bearing on the new, yet very old, word "velo," I remember that one day in April, when off the coast of Lower California, an intelligent Spanish gentleman referred to this very cloud condition as the "velo qui cubre la luz del sol." I also heard it spoken of as "el velo de la manana," showing that, while many phrases are used, the leading idea is the poetic one of a "veil."

THE VELO IS A CHARACTERISTIC CLOUD

While the *velo* cloud is common to the Pacific coast generally, and has been observed as far north as the Straits of Fuca, this cloud reaches its perfection over the littoral region of southern California. The *velo* cloud is the chief characteristic of the summer climate of the San Diego Bay region. And summer should be understood as covering all the year excepting November, December, January, and February. These four months could easily be reckoned as spring-time. The screening of this region from the sun's rays is so thoroughly accomplished that, during a normal summer's day, the sun breaks through the *velo* cloud about 10 o'clock, the sky clearing shortly afterwards and remaining free from clouds until about sunset. That the *velo* cloud is effective as a sun-shield, it needs only to be stated that the average of all the July maximum temperatures since weather observations began shows a mean of about 78 degrees.

The velo cloud over San Diego Bay—U. S. S. Pennsylvania

Dissipation of the velo cloud over Point Loma

The cause of the formation of the *velo* cloud and, consequently, the cool summers of San Diego, is, strange to say, found in the hot weather in the interior of California and Arizona. It is a unique example of the aptness of the proverb, "It's an ill wind that blows nobody good." The hot weather in the interior produces an aërial eddy (the "low" of the weather map), and the difference in atmospheric pressure between the interior and the ocean results in giving San Diego cool, uniform days and nights, free from extremes, or what is really the summer temperature of the Pacific Ocean. The *velo* cloud should therefore be incorporated in our local vocabulary, and it should replace the misnomer, "high fog."

CHAPTER III

CLOUD-FORMS IN SAN DIEGO

CHIEF among the characteristics of the weather in San Diego from November until March is the great variety and beauty of cloud-forms. It is unusual that, in a locality of such marked equability in temperature, abundant sunshine, and light rainfall, there should be such a variety in the formation of the clouds. The records of the Weather Bureau since their beginning in this locality, forty years ago, devote much space to this interesting and important meteorological feature. An examination of these records, and the taking of hundreds of cloud-photographs, together with personal observations extending through a period of over a dozen years, incline one to the belief that there is practically no variety of clouds which has not at some time been seen in San Diego. A discussion of local cloud-forms would, therefore, include nearly all of the known varieties and many that are uncommon to other lands.

The cause of cloudiness is the condensation of the water-vapor in the atmosphere. The composition of clouds includes all the various forms of suspended moisture, ranging from the water particles of the rain-cloud to the minute ice spiculæ of the high cirrus cloud. The type of cloud most likely to be formed depends on elevation, relationship to the great atmospheric centers of low and high pressure, and the physical configuration of the land.

EXPLANATION OF THE CLOUD-CREST ON POINT LOMA

A beautiful example of local condensation may be seen when the narrow promontory of Point Loma is covered with fog, while the rest of the atmosphere is clear. As the vapor is blown against the sides of this promontory, it is forced upwards a few hundred feet, and, according to the law that the temperature is lowered one degree for every 300 feet of ascent, the air is immediately cooled by expansion, the temperature of saturation is reached, and the crest of Point Loma is covered with a beautiful mantle of glistening fog, rivaling the historic "table-cloth" on Table Mountain in Cape Town, South Africa. As both the white mantle over Point Loma and the table-cloth on Table Mountain are produced by the same conditions, a rise in temperature of so much as a few degrees will dissipate these interesting spectacles. These illustrations show that moisture is mixed with the air, visible as fog, but always present whether visible or not.

EVERY CLOUD HAS ITS OWN INDIVIDUALITY

There are four distinct varieties of clouds—*stratus, cumulus, nimbus* and *cirrus*, and these are further separated into a total of ten classes. The study of the clouds in southern California is so interesting that it will well repay a brief consideration of their formation and significance. Beginning with the cloud nearest the earth we have the *stratus*, which is a uniform layer of cloud with an altitude of less than a thousand feet. In summer it is the *velo* cloud of southern California. The *nimbus*

cloud is the rain-producer, and it is frequently accompanied by brisk southerly winds. The *cumulo-nimbus* is the thunder-head of the spring and summer. These clouds are often seen towering over the Cuyamaca and Palomar Mountains, thrusting their snow-white masses several miles up into the air. They are always associated with the "Sonora" storms of spring. This form is the most transient of clouds, lasting in this region less than an hour. The *cumulus* is the fair-weather cloud, and is due to ascending currents of moisture-laden air. The *strato-cumulus* is distinguished by wave-like rolls of dark cloud through which the sun sends shafts of light, producing the spectacle of "the sun drawing water." The *alto-stratus* is a thick veil through which the sun may be faintly seen, and, as the sailors say, "making the stars look sick." In San Diego it is nearly always a threatening sky, as rain frequently follows its appearance. The *alto-cumulus* is another threatening cloud, but only when its fleecy masses show pendent hemispherical shapes. This is the cloud which supplies the brilliant red sunsets. The *cirro-cumulus* cloud is composed of small fleecy balls, and is sometimes seen in company with irregular streamers of *cirrus* cloud. These clouds are among the most beautiful to be seen in this locality. They assume parallel bands, which seem to converge and appear to give truth to Omar Khayyam, when he sang of the sky as "that inverted bowl they call the sky." In observing cloud-formations it should be borne in mind that perspective is responsible for the many illusions presented to the eye. The *cirro-stratus* is a still higher cloud, and its veil-like consistency gives a foreboding aspect to

Cirro-cumulus cloud over Coronado—Hotel del Coronado

Cirrus, alto-stratus, alto-cumulus clouds. Cumulo-nimbus in the distance (at sea)
From coal-bunkers wharf on San Diego Bay

the sky. This cloud produces the lunar and solar halos, "sun dogs," and kindred optical phenonema. The *cirrus* cloud is the highest cloud of any permanence in the category, having an altitude of from 10,000 to 30,000 feet, and, owing to this great height, it is composed of spiculæ of ice. This feathery cloud is of infrequent occurrence over southern California, as it is always associated with storm-areas. The appearance, direction, and duration of the *cirrus* wisps often constitute the best indication to the sailor of the location of storm-centers. Among the rare clouds seen in San Diego are "whirling cumulus," the spiral clouds of the upper atmosphere; the "festooned nimbus," from which the waterspout has its birth; and the evanescent "cloud banner," which streams out from Cuyamaca Peak.

CHAPTER IV

THE HUMIDITY OF THE AIR

THERE is considerable truth in the oft-repeated statement that "San Diego has the driest marine climate," provided, of course, that the comparison is made with other seaports of the United States. The phrase needs some explanation, for a "dry marine climate" might be more moist than a damp continental climate. Water is always present in the atmosphere, whether the air is so dry as to be uncomfortable, or so moist that fog obscures the vision. This vapor of water exists *in addition to the air*, and should be considered as a different element. The usual method of measuring the amount of moisture in the air is in percentages of saturation with relation to the temperature, hence the term *relative* humidity. In San Diego the relative humidity varies throughout the year, being greatest in the spring and summer months and least in the fall and winter. The average annual relative humidity is 75 per cent. The record shows that during the so-called "desert-winds" observations of but 2 or 3 per cent of relative humidity are not uncommon. This drying air is irritating to the nerves, owing to its effect on the tissues and membranes; but the good effect of this radical change in atmospheric surroundings cannot be overlooked. The thorough drying out and cleansing that is given the coast region makes mildew and mold, while common to most seacoast regions, unknown to the region about San Diego. Observations of the

physiological effect of damp air and dry air show that dampness depresses the nerves, induces sleep and slower circulation of blood, while dry air causes more or less nervous excitement, sleeplessness, quickens the pulses, dries the skin, and tends toward decreased bodily temperature.

The automatic registration of humidity also shows that the greatest relative humidity occurs shortly after midnight, and the least about noon. There is thus seen to be a close relationship between air-moisture and air-temperature, for the vapor-capacity increases proportionately with increase in temperature. When the relative humidity is low, the atmosphere is drying, or has a tendency to raise more vapor from water or damp soil. When, on the other hand, the relative humidity is high, there is little tendency to evaporation, and a slight fall in temperature leads to saturation and condensation.

TABLE I.—*Mean Relative Humidity, Twenty-four Years, 1888 to 1911*

January	71	July	80
February	74	August	80
March	74	September	78
April	75	October	76
May	77	November	71
June	79	December	67
Annual	75		

The chart (p. 14) gives the direction and humidity of the different winds that blow in San Diego, the length of the heavy line indicating the relative humidity of the wind, from each given direction.

It will be seen that the wind from the northeast is the driest, and the wind from the northwest the most humid; the latter carrying over four times as much moisture as the former. Relative humidity

depends not only upon the amount of moisture in the atmosphere in any given locality, but also, and largely, upon the actual exposure. For instance, while the relative humidity of the location may be as high as 80 per cent, the relative humidity in a room facing south or east, with open windows, may, because of its higher temperature, be as low as 50 per cent. Local environment plays a most important

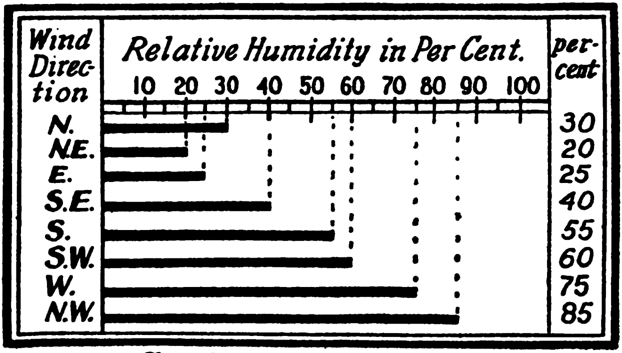


Chart showing moisture and winds

part in the physical effects of moisture. The climate of San Diego City is a cool, moist climate with much sunshine. If a drier atmosphere is required for residence, it would be necessary to go eastward into the desert region, where there is a dry, warm, and windy climate.

Humidity is a friend—not a foe, provided that the accompanying temperature is moderate. It is only when the air is hot and humid that the weather is sultry. "Raw winds" are possible only when the

temperature is low and the humidity is high. Balmy weather, so much sought for, may be considered as having temperatures varying from 65 to 75 degrees, with accompanying relative humidities of from 70 to 90 per cent.

There is no doubt but that the phrase "relative humidity" has been given too prominent a place in discussing the climatic advantages and disadvantages of a region. It is simply a ratio varying with temperature. As has been well said, "The absolute weight of the water-vapor, the relative purity of the air, and the frequency of ventilation are the things that count in the health-giving character of a climate."

CHAPTER V

"DESERT WINDS" AND DUST STORMS

ONE of the paradoxes of the climate of San Diego is its almost entire freedom from dust storms. Ordinarily the combination of sea breeze, abundant sunshine, and a location in a region having the desert conditions of less than ten inches of rain annually, would seem to make it an ideal region for frequent dusty winds. Dust storms require two elements, which are absent in this locality: First, finely divided soil and, second, brisk, drying winds. These conditions are often met with over the plains states—the states in the inter-mountain region and in the southwestern plateau region. In such localities the wind and dust are among the most disagreeable features. The highest wind occurs during the middle of the day, and carries with it the soil, which is commonly of a chalk-like consistency. This dust sifts through close-fitting doors and windows of residences and offices, its flour-like nature enabling it to enter nearly everywhere. Such is the condition generally described by residents of many western states.

WHY SAN DIEGO IS IMMUNE FROM DUST STORMS

San Diego is practically immune from dust storms because the soil is too coarse and the winds are not high. The soil in this region, being mostly of decomposed granite, is not light in weight, nor

does it occur in a pulverized state. While the winds are steady, they are not often brisk or drying. Of course, as one approaches the higher, drier, and more exposed localities, the winds are stronger and the air has less moisture. The local Weather Bureau Station has no record of storms of dust damaging either residents or vegetation, although a generation has passed since the establishment of the Station. The barometric pressure in southern California is remarkably even and free from extremes. New residents sometimes express themselves disgusted with the sluggish condition of their much-prized aneroid barometer, which, in their eastern homes, showed generous variation in pressure. In San Diego the barometer indicates little change from day to day; it averages a trifle below thirty inches, and it has a daily range of about one-tenth of an inch. This removes another factor in dust distribution, for it is a well-known fact that rapidly varying atmospheric pressure alternately pumps the air from "dust-proof" cabinets and cupboards, or drives in the dust-laden air.

The mechanics of the high, dry wind are among the most interesting features in meteorology. In the region of the plains states, the immense areas of high barometric pressure pour down masses of dry air, which becomes hot in summer, and is cold in winter. This high-pressure wind laps up moisture. In southern California the only high barometric pressure areas which can affect the local climate form either off the Washington or Oregon coast, or off the California coast; in both instances they generally move directly eastward. Once in a while these areas trend southeasterly, and they remain stagnant

long enough to set up air-circulation sufficient to affect the weather in San Diego. Then there occur what are locally termed "desert winds."

DESERT WINDS

If a stranger should ask a resident of southern California what month of the year is the warmest, he would very likely name November. And, if he should question further, he would probably be informed that it was the warmest because of the prevalence of the "desert winds," which are more common during November than in any other month of the year. The desert wind does not originate in the desert, even though the air-movement at such times is from nearly the direction of the desert. It partakes of that nature both in temperature and dryness. Its name differs with its habitat,—it is variously called a "norther" a "Santa Ana," or by the name of some other town north of the one experiencing such weather.

There are some desirable features in the desert wind,—it certainly does more good than harm to San Diego. It is as if the whole of the San Diego Bay region were transported to the mountains and the desert, and allowed to remain in that clear, bracing, and germ-destroying air for periods of two or three days.

Specimens of the cirro-cumulus and alto-cumulus clouds
over the manufacturing district of San Diego

Cumulo-nimbus clouds—Coronado shore

CHAPTER VI

FOG

BETWEEN the same parallels of latitude in the United States, the Pacific Coast experiences more frequent fog than the Atlantic Coast. The reason for this is that with the general drift of the air with the revolution of the earth, the winds of the Pacific Coast are mostly on-shore, while those of the Atlantic are off-shore. The distribution of fog on the Pacific Coast reaches its maximum at San Francisco, with moderately high averages north to the Canadian boundary, and decreasing in frequency and duration with the latitude, San Diego having the least on the coast.

Fog-charts, prepared by the Marine Division of the Weather Bureau, show that there have been fogs on the Pacific Coast which covered the shore-line from Canada to Mexico with a blanket of fog averaging fifty miles in width. So far as San Diego is concerned, the greatest fog-bank of which there is any record occurred a few years ago, when the fog extended 200 miles westward. Even when the fog is most dense it has only a slight vertical thickness. This fact was well borne out by the experiences of the naval officers in the fleet maneuvers off San Diego, in 1910, which were interrupted for a day or two only by fog. On one occasion the position of the ships of one of the squadrons could be discerned only from the military tops by noting the tips of the masts which showed above the fog.

FOG AND RAIN DIFFER ONLY IN EXTENT OF CONDENSATION

While fog, cloud, and rain are but differing degrees of condensation, there is not the relationship between fog and cloud that exists between cloud and rain. Concisely stated, the difference between rain and fog is that while rain is caused by expansion and consequent cooling of the air, fog is caused by the cooling of the air, either by radiation or by conduction. In the first process the water-vapor becomes visible as cloud whenever the air has carried the vapor upward till it has cooled by expansion to a temperature below the dew-point; in the other, the water-vapor becomes visible as a result, usually, of intermingling with air that had been cooled by the surface of the earth, which itself had lost heat by radiation. Fog always ends one of the three-day warm periods such as San Diego infrequently experiences. The explanation is as follows: The high barometric pressure, which primarily causes the high temperature during such periods, moves eastward and loses its effect over the Pacific slope. The consequent indraft from the sea brings quantities of warm and moist air over the cooler waters of the shore and bay. The irregularity of the fog-wreaths and -billows, and the erratic distribution of fog over the bay, may be assigned to the differing depths of water, for the deeper the water the cooler it is, and, therefore, the lower the temperature of the air immediately above it. These fog-banks and -billows make aërial signals, such as whistles and bells, uncertain and deceptive. Unless the fog is of uniform thickness, and is without intervening

pockets of fog-free air, submarine sound-signals are the only reliable warnings. The echo from the steamer's whistle will be returned by a vertical bank of dense, cold air as perfectly as if the sound had been reflected by the shore. Sometimes fog-billows may be seen almost to touch the water yet extend upward in rounded masses. Some of the most beautiful effects of sunlight on fog-masses are observed under such combinations of temperature and moisture. Daylight fogs are practically unknown in San Diego,

AVERAGE FREQUENCY OF FOG IN DIFFERENT MONTHS

In view of the rapidly increased shipping in and out of San Diego harbor, the following table will be found interesting and of value:

TABLE II.—*Number of Days with Fog*

January	2	July	1
February	2	August	1
March	1	September	2
April	2	October	5
May	1	November	3
June	1	December	1

A "day with fog" is one on which there is one hour or more of fog dense enough to obscure objects a thousand feet distant. The data are from the records of fifteen years' duration. During the year 1911 a detailed study of fog conditions was made, covering density and length of duration in hours and minutes. As that year was the foggiest known on the Pacific Coast, as well as in San Diego, it will be interesting to examine the data in detail. There were thirty-eight days with one hour or more of

fog, or a total of 188 hours, making an average of five hours' duration for each foggy day. The month with the longest duration was October, with a total of eighty-nine hours, and there was some fog during all the other months of the year, except July.

TABLE III.—*Number Hours of Fog in October, 1911. (The month with greatest fog record)*

1 A.M.	14	1 P.M.	0
2 A.M.	20	2 P.M.	0
3 A.M.	21	3 P.M.	0
4 A.M.	21	4 P.M.	1
5 A.M.	20	5 P.M.	2
6 A.M.	17	6 P.M.	2
7 A.M.	8	7 P.M.	6
8 A.M.	4	8 P.M.	8
9 A.M.	2	9 P.M.	9
10 A.M.	0	10 P.M.	10
11 A.M.	0	11 P.M.	12
Noon	0	Midnight	12

The hours of greatest frequency were between eleven at night and six in the morning. No fog occurred in the daytime between ten and four o'clock.

The beneficial effect of fog on the coast of southern California is apparent to anyone who has lived a year in this region. From the nature of the condensation it is impossible to measure accurately the amount of moisture conveyed by fog. There is no doubt that over a region covered by vegetation exposing a natural condensing surface, such as eucalyptus, palm, ice plant, etc., not less than a ton of water to the acre is thus distributed during the prevalence of every dense fog. Fogs not only supply considerable moisture to growing plants and trees, but, owing to the saturation of the air, evapo-

ration is at a standstill. In the interest of the law of compensation it would be interesting to prove a relationship between years of dense fog and like periods of scanty rainfall; but accurate fog records do not extend back farther than 1896, and fifteen years is too short a period to permit the drawing of satisfactory conclusions.

CHAPTER VII

THE RAINY SEASON IN SAN DIEGO

THERE is considerable misunderstanding on the part of the non-resident and recent arrival as to the amount, distribution, and character of the rains in southern California. It is often stated by a resident of another locality, "It never rains in San Diego!" while another will assert, "I never knew it to rain harder than at San Diego." Rainfall statistics for the past sixty years will show that there is some truth in both statements. San Diego has passed through a year with but three inches of rain, an amount which often falls in a single day elsewhere in the United States; and this city once received nearly twenty-eight inches of rain in a year. An examination of the rainfall statistics for this locality shows that the rainfall is chiefly remarkable for its irregularity in amount. Taking ten inches as the seasonal average, we have thirty-six years when it was less than ten inches, and twenty-four years when it was more. In the two generations which have passed since the rain-gage was first set up in old San Diego, not one year was like any preceding or following. On the contrary, the variation between the greatest and the least annual rainfall amounts to 800 per cent. The amount of rain is thus seen to be the least dependable of all climatic features in this locality.

In the distribution of rain throughout the year it will be seen that the rainy season generally begins in October. Over the greater part of the United

States there are no well-marked wet or dry seasons; but on the Pacific Coast very little precipitation occurs between the middle of May and the middle of October. The following summary is from sixty years of observations, and represents average conditions:

TABLE IV.—*Average Number of Rainy Days.*

	Rainfall Inches	Rainy Days		Rainfall Inches	Rainy Days
January	1.76	6	July	0.00	0
February	1.96	7	August	0.06	1
March	1.46	7	September	0.11	2
April	0.61	5	October	0.08	3
May	0.34	3	November	0.34	3
June	0.06	1	December	1.83	6

In the above table the rainfall is in inches, which means so many inches in depth of water on an average area. A "rainy day" is one on which one one-hundredth of an inch or more of rain falls. One one-hundredth of an inch is the smallest amount which can be measured, and it will be seen from the table that San Diego has an average of forty-four such days in a year. If we consider a quarter of an inch, this locality would have an average of fourteen such days a year, and one inch falls on an average of two days in a year. Since the beginning of records, San Diego has had a total of seven days when the rain exceeded two inches in any consecutive twenty-four hours.

The character of the rain in southern California is one of the distinctive features of the climate. Drizzling rains are uncommon, as mist is associated with precipitation only when the storms move in from the southwest. Nine-tenths of the rain in this region is caused by the low areas which enter the

Oregon-Washington coast and move eastward. Any southerly deflection of these storms is attended by threatening, rainy weather. A question often asked is, "If the storm comes from the north, how is it that our rain-winds are always southerly?" A steady southerly wind is our most favorable rain-wind, because the circulation of the winds in a storm, or "low" area, is always spirally toward the center, and with a direction, when viewed from above, opposite that of the hands of a clock. So that, as a storm drifts eastward, the wind veers to the southwest and west, and when the windvane points to the northwest we know that the rain is over, for the low area of barometric pressure is way to the eastward. This explains why San Diego is generally the last locality on the Pacific Coast to experience a rain, and the first to recover from its effects.

CAUSE OF RAIN

The average person seems often to mistake a mere coincidence for a cause, and to give it no serious thought. It is not strange, then, that many have placed the credit of rain to the Japan Current, to the Salton Sea, to preceding cold or warm summers in this region, or to preceding heavy rains in the mountains of Arizona or New Mexico. Some have even gone so far as to give credence to the moon or to the movement of other heavenly bodies. The manufacture of rain to order, by the use of explosives or gases, is still believed in by a very few uninformed persons. To those who have given much thought to the subject, it will appear that nature accomplishes results on such a vast scale that

even the more plausible causes, such as ocean currents and the proximity of inland bodies of water, would not explain the phenomena of rain. As shown in detail in a following chapter, the Japan Current, although looming large on popular maps, has no effect whatever on the weather over California.

Off the coast of California the surface-water has a southerly drift under the influence of the strong, prevailing northwesterly winds of summer, and it has a northerly movement during the other half of the year owing to the southerly winds of winter. It is thus seen that it is the wind which sets the surface-water in motion, and the wind is caused by the great atmospheric eddies. The formation, size, and drift of these aërial eddies are caused by the revolution and inclination of the earth, and the distribution of land- and water-masses. The Salton Sea myth, which was prevalent a few years ago, has now lost prestige, for even the most careful observer cannot see any connection between the variation of the size of this body of water and the variable rainfall of southern California. It would be a great satisfaction if any conection could be traced between the local rainfall and preceding warm or cold summers in San Diego, or preceding wet or dry summer months in the nearby mountains of Arizona; but graphic curves of departure from the normals of temperature and precipitation do not show coincidences, therefore these theories will have to be abandoned. As to the effect of the moon or stars on the weather, or the existence of "equinoctial storms," even a year's residence in San Diego is generally sufficient to convert the most credulous to the verdict of the meteorologist that there is nothing in

these theories, attractive though they be. As to the manufacture of rain, the subject may be dismissed by simply stating that careful laboratory experiments show no relationship between concussion and condensation.

There is always water-vapor present in the atmosphere, and cloud, fog, mist, or rain are the various degrees of condensation of vapor. Air-moisture is reduced to liquid water only by decreasing temperature. The formation of rain is the result of cooling by expansion against surrounding pressures as the air ascends. This process must be a continuous one, for, should all the vapor present in the air over a given locality be condensed at one time, the result under the most favorable conditions would seldom be a precipitation of more than two inches of rain. A continuous process is caused by the circulation of the air in an aërial eddy. In this aërial eddy, which is the "low" of the weather map, there is a radial inflow from all sides and an ascensional movement in the center. Once in a while heavy showers result, when the relationship between areas of high and low pressure is such as to cause cool, northerly winds to under-run the moisture-laden sea winds. In such infrequent instances the moist layer of air flowing above the other is cooled by convection in the same way that it is when it flows up and over a mountain, and rain follows.

CHAPTER VIII

A STUDY OF DRY SEASONS IN SAN DIEGO*

CONSIDERABLE apprehension has been felt as to the outcome of the present season in San Diego as regards rainfall. Twelve years ago similar conditions prevailed, and in the "Monthly Weather Review" of January, 1900, the editor discussed the light rainfall in San Diego, concluding with this statement:

> *It would, however, seem that there is little likelihood that the rainfall for the season 1899–1900 will be smaller than four inches, so that the three seasons just past will represent nothing worse than has happened twice before in ten years, namely, between 1855 and 1860, and between 1869 and 1872.*†

The seasonal rainfall for 1899–1900 was 5.97 inches, or 1.97 inches more than the estimated amount.

A perusal of the accompanying table will show that while the rainfall to date has been scanty it does not indicate that the balance of the season will be likewise dry. During the past sixty-two years San Diego has experienced six other years when the rainfall was less than that which has fallen so far this season. The record of these dry seasons is most instructive, as it gives us the only indication of what may be expected in the way of rain for the next few

*By the author, dated February 3, 1912, "Monthly Weather Review," Vol. XL, pp. 121, 122.

†"Monthly Weather Review," Vol. XXVIII, pp. 20, 21.

months. The examination of average conditions is rarely satisfactory for the reason that the normal seldom, if ever, occurs. With this fact in view, the following table has been compiled from the long rainfall record at this station. Only those seasons which resemble the present one have been considered.

TABLE V.—*Rainfall at San Diego, California—Number of Seasons in Sixty-two Years Where Less Than Half the Normal Was Recorded up to January 31*

Years	Months				Total, Oct. 1 to Jan. 31
	Oct.	Nov.	Dec.	Jan.	
1863–64	0.0	0.73	0.04	0.04	0.81
1872–73	.0	.0	1.43	.44	1.87
1876–77	.08	.04	.15	1.05	1.32
1882–83	.41	.39	.13	1.09	2.02
1886–87	.05	.95	.10	.04	1.14
1899–1900	.35	.86	.65	.69	2.55
1901–02	.28	.41	.02	1.70	2.41
1903–04	.07	.0	.35	.04	.46
1911–12	.28	.0	1.39	.66	2.33
Means	.17	.38	.47	.64	1.66

Years	Months				Total, Oct. 1 to May 31
	Feb.	March	April	May	
1863–64	2.50	0.20	0.01	1.25	4.77
1872–73	4.21	.11	.10	.03	6.32
1876–77	.18	1.44	.26	.43	3.63
1882–83	.95	.41	.31	1.14	4.83
1886–87	4.51	.02	2.14	.47	8.28
1899–1900	.03	.53	1.26	1.45	5.82
1901–02	1.57	1.86	.21	.06	6.11
1903–04	1.50	2.17	.15	.12	4.40
1911–12					
Means	1.93	.84	.56	.62	5.52

Cirrus and cirro-cumulus clouds attending the formation of a well-defined area of low barometric pressure. (One of Glenn Curtiss' pupils qualifying in altitude test)

The Bay of San Diego. Photographed above the U. S. Naval Coaling Station on Point Loma
Rain-sculptured rocks in foreground

The season of least rainfall, that of 1876–77, showed less precipitation than any of the previous twenty-seven years, and nothing has approached it in the thirty-five years that have elapsed. The history of that season shows that the last rain occurred on March 9, 1876, and until January 13, of the following year a total of only 0.65 of an inch was recorded. There appears to have been no damage to the orchards or inconvenience to other local interests, as the water-storage was ample for all needs at that time. After this ten months' drought nearly three and one-half inches of rain fell.

It will be observed that February 1 marks the middle of the rainy season in San Diego. During a normal year five inches of rain falls after this date. In a dry year, like the present, the records show that nearly four inches of rain is liable to fall between this date and the end of May.

TABLE VI.—*Normal Rainfall by Months*

September	0.06	March	1.70
October	0.46	April	0.74
November	0.83	May	0.41
December	1.82	June	0.03
January	2.00	July	.0
February	1.96	August	.0
Total	10.01		

During the dry seasons referred to above, the February rainfall averages 1.93 inches, generally falling in a few sharp showers accompanied by brisk to high southwesterly winds. In the cases where the March rainfall is considerable, like the years 1877 and 1904, the showers are more widely scattered. In fact, the records of the weather in San Diego during droughty periods indicate that down-

pours are common in February, and occur during northerly storms, while March and April rains frequently result from southerly storms. During May the rains are largely of the "Sonora" type, being overflows from the Arizona disturbances. Rains from such storms often follow dense fogs. The character of the weather during seasons of light rainfall is very distinct and constitutes a class by itself, as shown by the pressure, temperature, winds, humidity, etc., which have been examined for each of these individual seasons. The records of the last few dry seasons have been studied in connection with the daily weather map, and there is found to be a striking similarity in the distribution of the pressure-areas. The past seasons resemble the present in that the widespread high areas are persistent and greatly outnumber the lows in their frequency, and the former possess far more energy. While it is impossible to make seasonal forecasts, a perusal of the tables which accompany this article would indicate that there is little likelihood of San Diego experiencing a severe drought, but that, on the contrary, there is every reason to believe that this region will receive not less than three or four inches more of rain during this season.

NOTE.—No rain fell during the month of February, following the publication of this article; but in March 5.72 inches fell, followed by 2.13 inches in April.

CHAPTER IX

THE STABILITY OF THE CLIMATE

PERHAPS one of the most frequent remarks concerning the weather is positive assurance from some of the oldest inhabitants that the climate is changing. It is their conviction that the seasons are becoming drier or wetter, or that it is colder or warmer than it used to be. That the climate is changing cannot be denied; but this change is one covering thousands of years, and it is not compassed by the little span of recorded history. Though thousands of years have elapsed since the ice-sheet began its retreat, we have to go but a few hundred miles to the Yosemite National Park to see regions not yet beyond the glacial conditions of that epoch. It is thus seen that we are experiencing a phase of climatic oscillations which had its beginning many thousands of years ago. Climates change from age to age, but the systematic record of past events is limited to so short a space of time that no change has been observed, and no general increase or decrease either in temperature or rainfall. There are unquestioned secular fluctuations in climate, but the range of these undulations is probably over a generation long, and then they cover but a few inches in rainfall or a few degrees of temperature. It seems a far cry back to the golden days of '49, when the San Diego rain-gage was set up in the old Spanish mission; but how many hundred times fifty years have elapsed since the days when the lava met the sea at Point of Rocks at the Mexican

boundary? One is a historic period and the other is a geologic epoch.

The highest point reached in the annual temperature line of the above table is 63.8 degrees in 1867, and the lowest was in 1894, when 58.4 was recorded. It is thus seen that in half a century there was less than six degrees difference between the warmest and the coldest years. The temperature chart is valuable, not because it presents periodic fluctua-

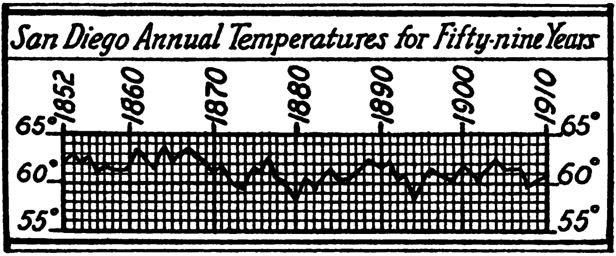
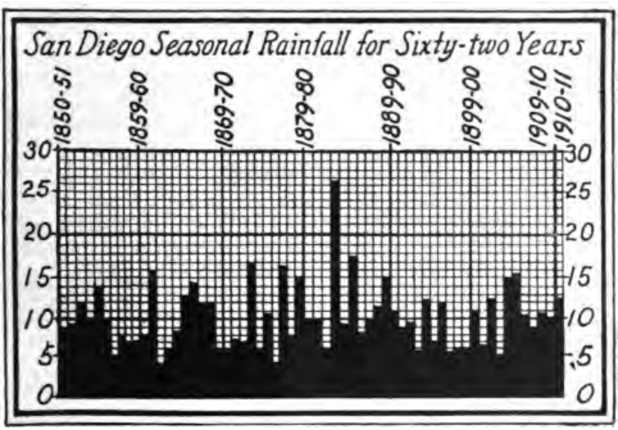


Diagram of annual temperatures for fifty-nine years

tions, but only in that it shows the slight range in temperature from year to year in San Diego since 1852. Mean annual temperatures for purposes of comparison are misleading, as they may be used to imply relationship where none exists. For example: The average annual mean temperature of San Diego is 61 degrees, which happens to be the same as Atlanta, Georgia; but the thermometer at the latter city has climbed nearly 10 degrees higher than that of San Diego, and has dropped 40 degrees lower.

In the rainfall chart, the year was made to end June 30, so as to conform more nearly to the sea-

sonal distribution. Eighty per cent of the annual rainfall of San Diego falls between November of one year, and March of the next. The average amount is 9.62 inches. The season recording the greatest amount of rain was that of 1883–1884, when 25.97 inches of rain fell. The season of least rain was that of 1876–1877, when 3.75 inches were recorded. A



Seasonal Rainfall Chart for sixty-two years

close inspection of this chart shows that the driest period ever known extended from 1869 to 1872, when the rainfall averaged 4.5 inches a season. The precipitation (rain and melted snow) increases back from the coast, so that within twenty-five miles of the city of San Diego the annual seasonal rainfall is five or six times greater. It will thus be seen that even during this four years' dry period there fell,

Table VII.—*Monthly, Seasonal, and Annual Rainfall at San Diego, California. (Elevation 93 feet).*

Season	July	August	Sept.	October	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1850	...	...	...	...	...	...	0	1.13	1.00	0.09	0	0.68	...	1850	7.84
1850–51	0	0	0	0.19	2.82	1.93	0.03	1.51	0.34	0.87	0.71	0.01	8.41	1851	7.49
1851–52	0	0	0.02	0.01	0.25	3.74	0.58	1.84	1.87	0.85	0.32	0	9.48	1852	11.87
1852–53	0	0.40	0	0.06	1.45	4.50	0.50	0.20	1.52	0.25	2.10	0.05	11.03	1853	7.88
1853–54	0	0.21	0	0	1.28	1.77	0.99	2.56	1.88	0.89	0.18	0.01	9.77	1854	11.63
1854–55	0.07	1.36	0.09	0.27	0.04	3.29	1.97	3.59	1.30	1.52	0.06	0	13.56	1855	11.15
1855–56	0	0.04	0	0.11	2.15	0.41	1.27	1.86	1.59	2.17	0.29	0	9.89	1856	9.77
1856–57	0	0	0.07	0	1.22	1.30	0.26	1.76	0	0.04	0.08	0.03	4.76	1857	6.15
1857–58	0	0.02	0.01	0.49	2.16	1.30	1.52	0.44	1.24	0.17	0	0.19	7.54	1858	7.55
1858–59	0	0.04	0.10	0.47	0.28	3.10	0	1.89	0.20	0.36	0.17	0	6.61	1859	6.10
1859–60	0.02	0	0	0.18	1.49	1.79	0.72	1.49	0.15	0.65	0.04	0.05	6.58	1860	9.11
1860–61	0.14	0	0	0	2.88	2.99	0.82	0.79	0.05	0.04	0	0.19	7.90	1861	7.92
1861–62	0	0	1.59	0.05	1.19	3.20	5.56	1.39	0.97	1.05	0.16	0.48	15.64	1862	11.59
1862–63	0.11	0	0	0.89	0.05	0.93	0.32	1.09	0.33	0.13	0.02	0	3.87	1863	3.02
1863–64	0	0	0.36	0	0.73	0.04	0.04	2.50	0.20	0.01	1.25	0.01	5.14	1864	7.61
1864–65	0.11	0	0	0.04	2.41	1.04	1.28	3.00	0	0.56	0	0.01	8.45	1865	7.52
1865–66	1.29	0	0	0.02	0.52	0.84	5.05	3.43	1.47	0.11	0.09	0	12.82	1866	12.31
1866–67	0	0.10	0	0	0.24	1.82	2.32	0.85	7.88	0.48	0.04	0	13.73	1867	15.72
1867–68	0	0.30	0	0.34	0.45	3.06	3.37	1.63	0.73	1.20	0.15	0	11.23	1868	11.16
1868–69	0.51	0	0.05	0	2.00	1.52	2.88	1.88	1.98	0.53	0.33	0	11.68	1869	10.96
1869–70	0.05	0	0	0.05	2.32	0.94	0.54	0.77	0.83	0.20	0.28	0	5.48	1870	4.37
1870–71	0.04	0.07	0	1.54	0.18	0.42	0.52	1.35	0.01	0.70	0.34	0	5.17	1871	5.64
1871–72	0	0	0	0	1.33	1.39	0.99	1.63	0.46	0.26	0.12	0	7.18	1872	5.07
1872–73	0	0.18	0	0	0	1.43	0.44	4.21	0.11	0.10	0.03	0	6.50	1873	13.07
1873–74	0	1.95	0	0	0.77	5.46	3.11	3.73	1.20	0.34	0.32	0	16.88	1874	10.91
1874–75	0.12	0	0.13	0.53	0.88	0.55	2.38	0.37	0.45	0.12	0.20	0.02	5.73	1875	6.80
1875–76	0	0.21	0.39	0	2.25	0.41	2.47	2.44	1.78	0.06	0.05	0.05	10.11	1876	7.24
1876–77	0.03	0.06	0.03	0.08	0.04	0.15	1.05	0.18	1.44	0.26	0.48	T	3.75	1877	8.12

1877–78	0	0	0	0.81	0.06	3.89	1.45	4.83	1.41	2.91	0.58	0.16	16.10	1878	13.87
1878–79	0	0	0	0.96	0	1.57	3.54	1.04	0.10	0.60	T	0.07	7.88	1879	14.71
1879–80	0	0	0	0.29	2.77	6.30	0.61	1.50	1.43	1.34	0.06	0.06	14.36	1880	10.37
1880–81	0.09	0.32	0	0.53	0.28	4.15	0.52	0.45	1.88	1.35	0.04	0.05	9.66	1881	5.00
1881–82	0	0.01	0.04	0.24	0.12	0.30	4.53	2.55	1.02	0.45	0.18	0.07	9.51	1882	9.74
1882–83	0	T	0.01	0.41	0.39	0.13	1.09	0.95	0.41	0.31	1.14	0.08	4.92	1883	8.01
1883–84	0	0	0	2.01	0.20	1.82	1.34	9.05	6.23	2.84	2.17	0.31	25.97	1884	27.59
1884–85	0	T	0.07	0.35	0.11	5.12	0.35	0.02	0.78	1.20	0.61	0.06	8.67	1885	5.73
1885–86	T	0.13	T	0.31	1.56	0.71	6.95	1.51	3.73	1.95	0.04	0.07	16.96	1886	15.35
1886–87	T	T	0	0.05	0.95	0.10	0.04	4.51	0.02	2.14	0.47	0.04	8.32	1887	10.45
1887–88	0.01	T	T	T	2.08	1.14	1.96	1.48	2.79	0.10	0.22	0.04	9.82	1888	11.57
1888–89	0.01	T	0.04	0.26	1.83	2.84	1.72	1.80	2.20	0.19	0.03	0.10	11.02	1889	16.08
1889–90	T	0.04	T	2.12	0.12	7.71	2.79	1.70	0.41	0.05	0.08	0	15.02	1890	8.02
1890–91	0	T	0.65	0.01	0.72	1.61	1.21	4.84	0.27	0.76	0.35	0.05	10.47	1891	8.99
1891–92	T	0	0.08	0.04	0.10	1.29	1.58	2.96	0.96	0.41	1.15	0.13	8.70	1892	9.09
1892–93	0	0.05	T	0.22	0.94	0.69	0.78	0.47	5.50	0.22	0.39	T	9.26	1893	10.29
1893–94	T	0	0	0.11	0.91	1.91	0.29	0.49	1.05	0.11	0.09	0.01	4.97	1894	4.35
1894–95	0	0.04	0.01	T	0	2.26	7.33	0.53	1.43	0.11	0.19	0	11.90	1895	11.33
1895–96	0	0	0.01	0.27	1.19	0.27	1.27	0.02	2.89	0.25	0.03	0.01	6.21	1896	8.73
1896–97	T	0.13	T	0.97	0.98	2.18	3.13	2.72	1.53	0.02	0.12	T	11.78	1897	8.93
1897–98	0.01	T	T	1.06	0.02	0.32	1.71	0.06	0.91	0.22	0.66	0.02	4.99	1898	4.67
1898–99	0	0	0.07	0	0.15	0.87	2.34	0.30	0.85	0.29	0.10	0.27	5.24	1899	6.08
1899–00	0	0.07	0	0.35	0.86	0.65	0.69	0.03	0.53	1.26	1.45	0.08	5.97	1900	5.77
1900–01	0	T	T	0.30	1.43	0	2.08	4.77	1.07	0.01	0.77	0.02	10.45	1901	9.49
1901–02	T	T	0.06	0.28	0.41	0.02	1.70	1.57	1.86	0.21	0.06	T	6.17	1902	11.49
1902–03	0.92	T	T	0.06	1.53	3.58	0.69	2.27	1.17	1.40	0.14	T	11.76	1903	6.09
1903–04	0	T	T	0.07	T	0.35	0.04	1.50	2.17	0.15	0.12	0	4.40	1904	6.61
1904–05	0	T	T	0.17	0	2.46	2.16	5.90	2.98	0.30	0.35	T	14.32	1905	16.36
1905–06	0.16	0	0.50	0.25	3.38	0.38	0.98	2.62	4.68	0.98	0.72	0.03	14.68	1906	14.90
1906–07	T	0.10	0.12	0.03	0.62	4.02	3.27	0.45	1.62	0.13	0.07	0.19	10.62	1907	7.95
1907–08	0.03	0	0	1.71	0.05	0.43	2.80	2.41	0.61	0.35	0.16	0	8.55	1908	8.59
1908–09	0	0.64	0.20	0.15	1.60	0.27	3.57	1.76	2.62	0.02	T	T	10.23	1909	14.14
1909–10	T	T	0.02	0	2.39	3.76	2.00	0.19	1.30	0.08	0.05	0	9.79	1910	5.75
1910–11	0.01	0.05	0.17	1.35	0.40	0.15	3.35	4.92	0.92	0.65	0.01	0.01	11.99	1911	11.77
1911–12	0.12	0	0.10	0.28	0.02	1.39	0.66	0	5.72	2.13	0.17	.16	10.75	1912	...
Means	0.06	0.11	0.08	0.34	0.95	1.83	1.76	1.96	1.46	0.61	0.34	0.06	9.62		9.54

T indicates Trace.

Table VIII—*Showing Highest and Lowest Temperatures Registered During each Month from January, 1874, to June 30, 1912, at San Diego, California.*

Year	Jan.		Feb.		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1872.......	73	37	68	44	71	44	74	43	83	52	80	55
1873.......	75	44	77	37	72	40	82	42	78	52	75	58
1874.......	71	42	64	41	63	41	71	43	74	50	76	52
1875.......	68	42	70	44	71	39	77	39	82	50	77	53
1876.......	65	39	77	39	75	43	87	43	76	50	88	51
1877.......	78	42	75	45	70	48	67	44	68	51	94	55
1878	68	38	69	44	68	42	77	44	73	48	76	51
1879.......	76	35	74	38	99	44	82	45	94	47	93	52
1880.......	73	32	63	35	69	38	80	42	84	46	73	52
1881.......	70	36	82	39	72	40	82	51	72	51	76	53
1882.......	64	34	70	37	79	39	70	43	73	48	75	55
1883.......	76	32	83	36	71	48	85	42	89	45	84	56
1884.......	78	39	79	38	68	43	69	45	72	47	81	50
1885.......	68	38	76	40	81	42	83	47	73	52	74	52
1886.......	74	35	80	44	68	41	71	45	72	50	75	54
1887.......	74	38	76	38	82	44	80	44	79	48	78	54
1888.......	64	33	67	42	72	41	93	47	70	52	76	54
1889.......	78	36	85	37	80	45	83	47	80	50	72	56
1890.......	66	35	77	38	74	41	85	45	75	46	93	51
1891.......	76	35	70	34	76	41	77	44	67	53	78	53
1892.......	75	38	68	42	73	44	80	41	87	47	75	51
1893.......	80	38	75	40	75	40	78	43	88	49	75	53
1894.......	69	32	69	34	72	36	83	43	72	45	73	50
1895.......	77	36	82	39	74	38	81	44	80	51	77	51
1896.......	77	39	83	39	85	41	74	42	98	48	89	54
1897.......	73	40	76	38	70	40	88	46	67	50	70	54
1898.......	78	36	75	42	77	38	86	45	69	51	88	54
1899.......	74	43	76	34	86	44	93	46	66	48	70	55
1900.......	79	46	76	45	80	46	67	45	75	49	87	56
1901.......	75	40	83	44	82	47	66	46	67	51	86	53
1902.......	81	36	71	39	76	43	69	47	78	50	76	52
1903.......	78	43	75	35	72	42	73	47	68	50	74	54
1904.......	83	36	68	41	74	44	78	44	69	48	74	56
1905.......	73	46	79	40	76	38	68	44	77	48	70	54
1906.......	72	35	76	47	80	41	88	42	70	50	89	53
1907.......	73	35	84	41	82	40	75	43	73	51	80	52
1908.......	80	44	68	37	78	42	83	46	68	47	70	50
1909.......	70	42	74	41	74	42	82	46	87	50	77	53
1910.......	76	34	72	37	84	45	96	47	75	46	71	54
1911.......	77	41	70	34	77	44	79	44	74	49	91	53
1912.......	82	40	74	43	71	45	67	45	72	49	72	54

TABLE VIII.—*Showing Highest and Lowest Temperatures Registered During each Month from January, 1874, to June 30, 1912, at San Diego, California, continued.*

YEAR	July		August		Sept.		October		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1872.......	75	58	86	60	80	54	87	45	81	42	72	40
1873.......	77	60	78	63	82	55	76	49	85	49	68	44
1874.......	79	59	83	56	78	54	90	46	75	45	82	39
1875.......	79	61	83	63	88	57	88	53	78	50	75	38
1876.......	78	60	81	60	82	54	80	48	79	43	77	43
1877.......	86	59	82	58	91	58	73	47	78	46	78	40
1878.......	77	56	80	55	100	53	87	44	77	40	79	35
1879.......	75	58	81	54	92	54	92	46	79	43	71	32
1880	73	54	84	56	82	50	81	48	78	40	77	40
1881.......	80	57	82	56	86	52	72	46	76	38	77	39
1882.......	78	57	83	62	80	50	81	49	80	42	78	41
1883.......	80	59	84	60	101	59	80	48	82	43	78	42
1884.......	84	54	92	54	78	51	87	47	74	42	68	36
1885.......	82	58	89	62	90	56	88	47	76	42	79	40
1886.......	81	57	82	61	78	60	75	47	77	40	76	40
1887.......	79	60	77	54	79	58	85	50	82	44	74	36
1888.......	77	55	82	57	82	58	80	53	75	46	73	44
1889.......	84	59	89	62	91	54	80	52	83	46	69	40
1890.......	80	56	89	58	83	60	90	49	91	46	79	47
1891.......	88	58	85	60	89	55	84	50	82	44	72	32
1892.......	75	57	80	57	80	54	83	46	84	40	71	36
1893.......	79	57	81	59	77	53	88	50	83	40	82	38
1894.......	77	57	90	55	90	52	87	45	78	45	70	41
1895.......	74	57	78	54	90	54	84	54	85	38	79	34
1896.......	80	56	88	59	80	54	79	52	76	43	76	46
1897.......	79	59	89	60	83	58	76	51	83	45	80	36
1898.......	77	60	83	63	91	56	81	51	76	43	79	43
1899.......	78	57	76	58	92	55	93	48	81	50	80	46
1900.......	84	60	80	59	87	53	72	50	89	51	79	44
1901.......	74	57	79	58	72	56	96	51	80	49	76	35
1902.......	76	55	79	60	73	56	71	52	74	42	74	40
1903.......	78	59	85	60	83	56	84	51	84	45	75	44
1904.......	76	59	82	63	86	56	94	53	93	48	78	44
1905.......	74	59	88	58	81	55	85	50	80	44	74	38
1906.......	82	58	78	57	91	58	89	46	86	39	80	41
1907.......	81	59	75	60	79	50	78	54	86	45	79	43
1908.......	80	56	79	60	84	52	80	48	76	42	69	37
1909.......	79	58	93	59	100	53	94	49	85	42	71	36
1910.......	82	56	82	58	86	56	87	50	74	43	74	40
1911.......	93	59	84	58	76	54	84	50	82	44	78	36
1912.......												

within a short distance of San Diego, not less than an average of twenty-five inches of rain. Strictly scientific conservation of this dependable precipitation will insure an ample and stable water-supply for San Diego and vicinity.

CHAPTER X

THE EQUABILITY OF THE CLIMATE

THE climate of San Diego is characterized by uniformity of temperature and invariability of sunshine. The temperature covers a short range, and the sunshine is even more constant in winter than in summer. San Diego may truthfully be said to have the shortest thermometer in the United States, with one exception (the southeast Farallone Island). These statements are accepted by the meteorologist from his comparative studies of other climates, and by the resident as a matter of almost unconscious observation; only to the non-resident do these facts appear almost beyond belief.

The chief cause of San Diego's salubrity of climate lies in its latitude. Among other causes are: Its location to the leeward of the ocean, its distance from the eastward-moving storms of the northern coast, and the absence of mountains close to the sea. The latitude gives a temperate climate, the proximity to the sea equability of temperature, the distance from the storm-tracks freedom from high winds and rough weather, and the absence of mountains in the immediate neighborhood contributes to infrequent cloud or fog.

INFREQUENCY OF HOT AND COLD PERIODS

The most severe test which can be applied to any climate is an examination of the extremes of weather conditions as they appear in a long, unbroken,

automatic record. From a study of half a century of the weather conditions in San Diego, it is found that the average of the three consecutive warmest days was 82.9 degrees, occurring in September, and the average of the three consecutive coldest days was 40.2 degrees, recorded in January. For twenty-five years the temperature has been continuously recorded by automatic instruments, and during this period the thermometer has been lower than 80 degrees on an average of 364 days a year. The extremes at San Diego are 101 and 32 degrees. The thermometer touched 90 degrees on an average of four hours a year, and dropped to 40 degrees or lower on an average of 10 hours a year. The average daily range of the thermometer is 13 degrees. The average difference between the mean temperature of one day and that of the next is 2 degrees. San Diego is one of three places in the United States where the thermometer has not been lower than 32 degrees, viz, Key West, southeast Farallone, and San Diego. Practical illustrations of the equability of temperature are found in the facts that only a small amount of fuel is used locally for heating, and but little more ice is used in summer than in other seasons of the year.

TABLE IX.—*The Average Highest and Lowest Temperatures in the Year*

	Mean Max.	Mean Min.		Mean Max.	Mean Min.
January	62	44	July	74	61
February	62	47	August	75	63
March	63	50	September	74	63
April	66	52	October	70	58
May	68	55	November	68	52
June	70	57	December	65	48

THE SUN SHINES ON AN AVERAGE OF 356 DAYS A YEAR IN SAN DIEGO

Photographic or electric sunshine instruments have faithfully recorded the sunshine in San Diego for the past twenty years, and, during this time, there has been an average of less than nine days a year without one hour or more of sunshine. Strange as it may seem, the cloudiest days are in spring or summer, when the *velo* cloud effectually screens the sun's rays, causing the distribution of sunshine to be less in summer than in winter.

TABLE X.—*Per Cent of Possible Sunshine*

January	67	July	67
February	66	August	72
March	64	September	73
April	69	October	73
May	58	November	76
June	60	December	75
Year	68		

Perusal of foreign climatic charts gives truth to the statement that the coast of southern California bears the same relationship to America that the region about the Mediterranean does to Europe, and what the Riviera is to the Mediterranean, San Diego is to southern California.

CHAPTER XI

CLIMATIC FACTORS IN BUILDING

AS affecting residence, local variation in climate is one of the most interesting studies, for San Diego, like all regions with climatic advantages, has well-marked general and specific variations. These variations are caused by exposure to the sun and wind, drainage of air as well as water, and elevation.

One of the first errors to be corrected is a misapprehension of the general character of the climate as regards temperature. It must be remembered that the climate of San Diego is not tropical, nor even semi-tropical, but that it is, in every meaning of the word, a temperate climate. We soon learn that we cannot wear the clothing of the semi-tropics, that our houses have to be heated in winter, that in summer out-of-door porches for lounging are nearly useless, because of the cool evenings, and that lawns are made for looks and not for use. A frequent question asked during the summer as well as the winter is, "When does it get warm in San Diego?" San Diego is relatively warm or cool; that is, it is warm in winter and cool in summer, by comparison with other places in the United States. For example, the early part of the year 1912 was mild throughout the entire United States, yet the cool mornings and nights prompted many to ask where they could go for a warmer climate. In nearly every instance where the daily telegraphic temperatures were compared, San Diego was shown to

have the highest minimum temperature. San Diego has a cool climate throughout the year, and yet with these moderate temperatures semi-tropical plants have uninterrupted growth. It is one of the rare localities where northern and southern vegetation flourish side by side. In many gardens pines and palms fraternize, banana and lemon trees blossom and bear during all the months of the year, and there are rose bushes that have been covered with flowers every day for a dozen years or more. With this proof of the absence of killing frost there is still a tonic in the air, a bracing quality compounded of a moderately high percentage of moisture and comparatively low temperature. This feature is unknown in other southern regions, and puts at rest all fears of San Diego having an enervating climate.

There are few cities of its size in the United States where so much building is constantly going on as in San Diego. In southern California there need be no delay in building operations, for there are no interruptions on account of weather conditions. Those contemplating building a residence here should carefully consider the position of the building-site, its exposure to the sun and wind, elevation, and character of the soil. As a rule, view lots are windy ones. But, although the house fronts the west, which for some reasons is the best frontage, the south and east sides can be arranged to admit the sunshine and drier winds. The location of a residence in this locality with relationship to the prevailing winds is of considerable consequence. In the chapter on Humidity will be found a diagram showing the frequency of wind-direction and humidity. This diagram should be useful to constructors. Air-

drainage must be considered apart from the general winds, although in cañons and valleys the down-rushing air of evening and the up-rushing air of morning appear to the observer as an ordinary cold breeze.

Cold air flows down hill, and a location in a hollow or in a depression on a hillside is to be avoided because of this fact, and because of the accumulation of cold air in such pockets. Owing to such a flow of air it is much better to build a little beyond the brow of a hill than on the hillside or on the immediate crest.

SUNSHINE AND VENTILATION

In Rome, rooms with a southern or eastern exposure command a much higher rent, being more desirable on account of the sunshine. Exposure to the sun in San Diego is no less beneficial; and the importance of giving a house full access to the sun's rays is equal only to the exposure of the house with relation to the prevailing winds. The ideal house is one with the east, southeast, and south sides mostly of glass. Such an arrangement does away with much artificial heating. A building is best warmed by a furnace, steam-radiator, or open grate; oil or gas heating stoves are not hygienic unless a room is thoroughly ventilated. Ventilation is especially important in San Diego because there is little daily change in atmospheric pressure. This is quickly noticed in going into a closed room where the air is found to be "stale." If the occupants are in good health, the temperature of a room may safely be kept not over 10 or 15 degrees above the outside

air in December, January, and February. From March to November the air of the living-room should correspond closely with the outside air-temperature.

As a climatic factor, elevation above sea-level is not so important here as elsewhere. Altitude gives the advantage of less moisture, but the disadvantage of more wind. This may not seem true ordinarily, but it should be remembered that San Diego is a seaport and, consequently, has a higher average wind velocity than interior towns. While low elevation always accompanies more or less stagnant air, there is a compensation in less range of temperature between night and day.

Another feature which should be given careful consideration is solidity of foundation. This may seem to appear of minor importance now, but it is well to take precautionary measures for the future. The foundations of structures should go down to natural earth; that is, "fills" should be penetrated to the underlying hardpan. All "made" ground is subject to settling, and, owing to its nature, it is in a state of unstable equilibrium.

CHAPTER XII

THE COAST, MOUNTAIN, AND DESERT CLIMATES OF SAN DIEGO COUNTY

WHILE much has been written about the equability of the climate of San Diego Bay region, little has been said about the great diversity of climate to be found within the limits of the county. Some of the contrasts in temperature and precipitation within this relatively small area are so great that, without the authority of government statistics, they would appear impossible. The Chinese empire has been called "the paradise of the man with the long-bow," because, as a Chinaman is loth to collect statistics, it allows the traveler to invent almost any tale, as it cannot be contradicted by available data. This is not so in San Diego, for it is a matter of history that, after the landing of Fremont's troops in the late forties, reliable weather records were commenced and have been maintained ever since.

It is upon such statistics that the following account of the varying climatic conditions is based:

SAN DIEGO COUNTY HAS THREE DISTINCT CLIMATES

There are three distinct climates to be found within the limits of San Diego County. They are: First, the nearly sub-tropical coast climate of the San Diego Bay region; second, the climate of the mountainous district a score of miles back from the coast; and third, the desert climate another score

TABLE XI.—*San Diego County Data. Temperature, Precipitation, and Character of Weather**

	Cuyamaca	El Cajon	Escondido	Mammoth Tank	Poway	San Diego
Average Temperature	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.	Degrees Fahr.†
January	37.0	53.8	49.6	53.9	48.0	54.0
February	36.1	52.8	52.0	58.9	49.5	54.6
March	39.9	55.7	54.3	66.1	52.4	56.2
April	43.9	58.2	58.3	75.4	55.8	58.2
May	49.5	62.4	62.6	83.6	60.6	60.8
June	60.7	67.2	67.9	92.5	65.1	63.8
July	65.0	71.3	72.5	98.5	68.9	66.9
August	64.5	71.0	72.1	96.8	69.6	68.7
September	59.0	69.0	69.0	90.0	65.9	66.9
October	49.6	64.2	61.5	76.8	59.4	63.0
November	44.7	60.1	55.1	63.8	53.5	59.0
December	38.7	54.6	49.5	55.4	51.1	55.7
Annual	49.0	61.7	60.4	76.0	58.3	60.6
Mean precipitation (rain and melted snow)	Inches	Inches	Inches	Inches	Inches	Inches
July	0.27	0.10	0.01	0.06	0.04	0.06
August	0.64	0.11	0.08	0.34	0.03	0.11
September	0.60	0.12	0.08	0.04	0.08	0.08
October	1.76	0.50	0.53	0.11	0.50	0.34
November	3.35	1.39	1.24	0.11	1.22	0.95
December	5.07	1.28	1.35	0.35	1.88	1.83
January	6.98	2.43	3.86	0.16	3.19	1.76
February	7.88	2.67	2.80	0.52	2.64	1.96
March	7.97	2.71	3.02	0.20	2.65	1.46
April	2.30	0.63	0.85	0.09	1.13	0.61
May	2.19	0.44	0.64	0.02	0.54	0.34
June	0.25	0.11	0.10	....	0.07	0.06
Seasonal	40.07	12.94	15.21	2.02	13.96	9.62
Annual	38.84	12.24	15.15	1.99	13.79	9.54
State of weather	Aver. days	Aver. days	Aver. days	Aver. days	Aver. days	Aver. days
Rainy	60	44	39	5	36	43
Clear	220	266	143	292	240	266
Partly cloudy	79	59	191	22	66	49
Cloudy	66	40	31	51	59	50
Wind	W	SW	W	W	W	NW

*Section 13, "Summary of Climatological Data for the United States."
†Normal temperature for thirty-three years.
NOTE.—The elevations at which these observations were made are as follows: Cuyamaca, 4,677 feet; El Cajon, 482 feet; Escondido, 657 feet; Mammoth Tank, 257 feet; Poway, 460 feet; San Diego, 93 feet.

of miles farther east. The seasonal distribution of precipitation and the usually clear skies are common to all of southern California. A brief classification would give the immediate San Diego Bay region cool summers and warm winters; slight variation in temperature from day to night; slight but steady wind movement; moderately high relative humidity, and frequent rainfall in limited amounts.

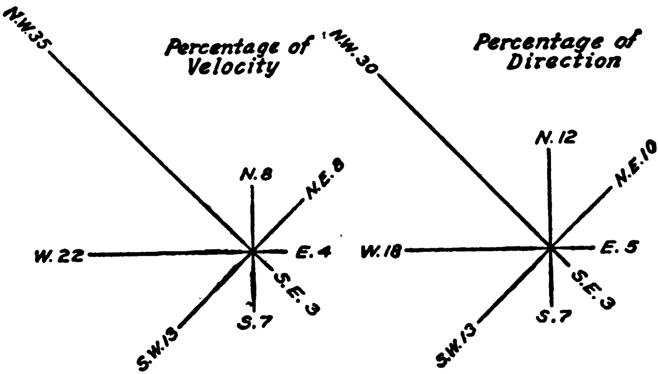
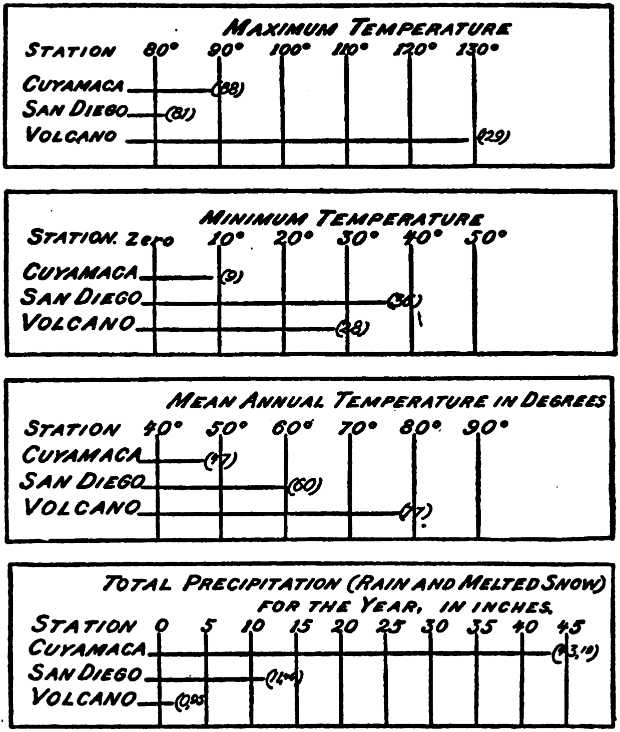


Diagram of relative wind velocity and frequency

The mountainous region of San Diego County has warm summers and cool winters; considerable range between day and night temperatures; fresh daylight winds; low relative humidity, and moderately heavy winter rains supplemented by summer thunderstorms. The desert climate of this region is the most perfect exponent of its type, being notable for constant and unvarying sunshine; warm winters, with great variation between night and day temperatures; hot summer days without cool nights;

extremely low relative humidity; brisk daylight winds, and practically no rainfall.

The principal features of the three climates are shown graphically in the following diagrams. In-

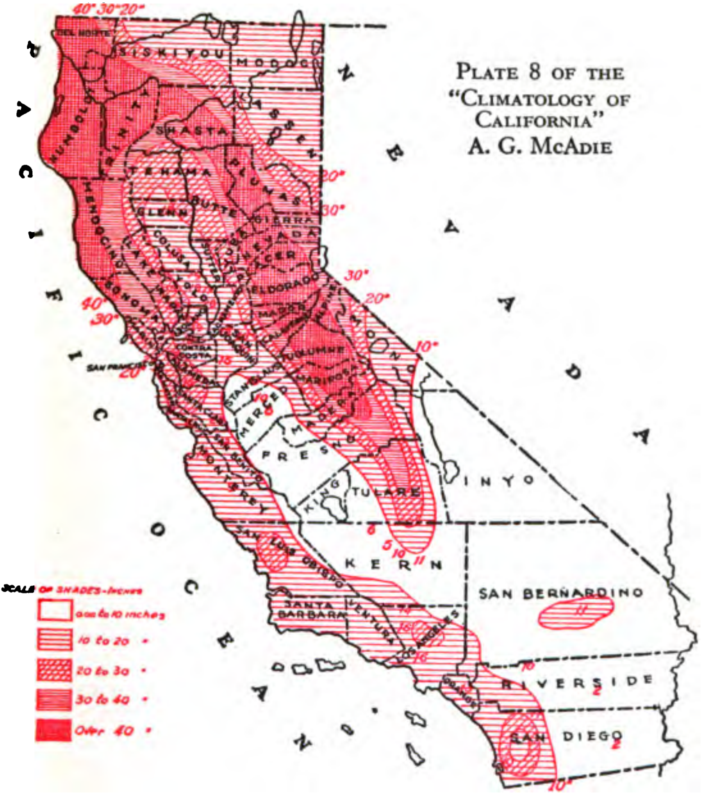


Comparative coast, mountain and desert temperatures, and precipitation

these diagrams the records of the year 1902 are used, as that year more nearly approached normal conditions and thus facilitated comparison. The city of San Diego, with an elevation of 93 feet, is taken as representative of the coast climate; Cuyamaca, with an elevation of 4,677 feet above sea-level best shows the mountain climate; and the desert conditions at Volcano Springs (now within the contour of Salton Sink), because that station was 220 feet below sea-level.

It is perhaps unnecessary to state that the temperatures in the above tables were all made with standard Weather Bureau thermometers, exposed in ventilated instrument shelters, and therefore show shade temperatures. In the desert regions it is not unusual for the mean monthly temperature to average 100 degrees, while on the coast, at San Diego, there have been periods covering three consecutive years (1891–93) when the thermometer failed to register so high as 90 degrees. There is likewise a remarkable divergence in rainfall between continuous regions of mountain and desert. Years have passed on the desert without so much as a few inches of rain, yet San Diego County also has the record of the heaviest downpour in the United States. This record was made at Campo on August 12, 1891, when 16.10 inches of rain fell—11.50 inches of this amount fell in eighty minutes.

An important fact to remember is, as General Greely says, that "the region of equable temperature covers less than forty square miles," and that in equability the climate reaches its perfection within the city limits of San Diego.



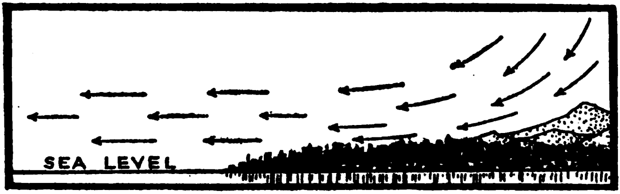
Precipitation map of California (after McAdie), showing that in the vicinity of San Diego exists the region of heaviest rainfall in southern California.

CHAPTER XIII

THE LAND-AND-SEA BREEZE

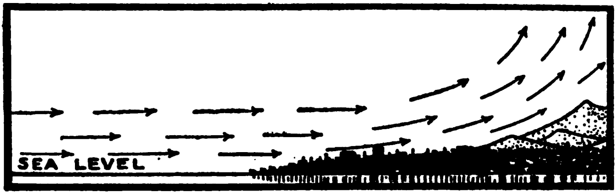
IT appears to be the universal testimony of persons who have temporarily been absent from this locality that their memory most often recurs to the winds of San Diego. This is readily accounted for when we find that the average wind velocity of San Diego is low for a seacoast port, being less than six miles per hour, and that high winds are practically unknown. These conditions are brought about mainly by the proximity of the sea and desert. The latitude is such as to remove from all but casual consideration the effect of the northern storms, which generally enter the Pacific Coast about the latitude of Oregon and move eastward. Unless the storm be of unusual size or intensity, the wind-system of San Diego is not disturbed. The sea breeze is most constant, and blows from the northwest during all but two months in the year—June and December—when the winds are from the southwest and northeast. The annual distribution of the wind would give the following percentages from eight points of the compass: North and northeast, 8; east, 4; southeast, 3; south, 7; southwest, 13; west, 22; and northwest, 35 per cent. In the course of the year about 50,000 miles of wind traverse San Diego. May is the month with the greatest amount of wind, and December records the least. For over twenty years recording instruments have traced on paper every mile of wind and, for every minute, the direction of the wind. The compiled records show

some interesting figures. Before considering the average conditions let us examine the extremes, for the unusual features in the climate of any locality are the most convincing. The Weather Bureau



The land-breeze. Ideal circulation (water warmer than land) 3 A.M. to 9 A.M.

designates winds of from 0 to 5 miles an hour as "calm," 5 to 15 as "light," 15 to 25 as "moderate," 25 to 35 as "brisk," 35 to 50 as "high," 50 to 65 as a gale, and from 65 above as a hurricane. Under



The sea-breeze. Ideal circulation (land warmer than water) 11 A.M. to 6 P.M.

this classification San Diego has a "brisk" wind (25 to 35 miles an hour) about three times a year. Once has the wind exceeded 40 miles an hour, and that was 43 on March 9, 1912. For the past decade the records of the local office of the Weather Bureau

have been used by many foreign meteorologists to illustrate the constancy of the land-and-sea breeze, which is caused by the unequal heating of the land and water. In San Diego this breeze is said to attain perfection in the regularity of the change in wind-direction. Although nearly one-half of the wind is from the northwest and a point near the west, the land-and-sea breeze feature gives San Diego some wind-movement from all directions. It must be understood, however, that the land breeze is unusually light, averaging less than 4 miles an hour. It blows from about three until nine in the morning, when there is nearly a calm. The period following the land breeze lasts a couple of hours, and is analogous to the term "slack-water" in the tides. The time of this calm period between the land breeze and the sea breeze changes, of course, with the season, being earlier in the summer and later in the fall and winter. In January it covers nearly all the morning hours.

CHAPTER XIV

AVIATION AND AIR-MOVEMENT IN SAN DIEGO

ABOUT ten or twelve years ago a gray-haired gentleman walked into the Weather Bureau office and introduced himself as Octave Chanute. This was the first visit of the noted French engineer to San Diego. Led by the attractive record of San Diego's low wind velocities he came here in pursuit of his studies in aviation. After Langley, no scientist here or abroad contributed more to the progress of practical navigation of the air than did Octave Chanute. At the time of Chanute's first visit to San Diego, pelicans were very numerous on the bay, and, in company with his assistants and friends, he made many instantaneous photographs of these interesting and picturesque birds. He once told me that the secret of air-navigation lay in imitating the flight of the pelican. Hundreds of photographs were taken, to be studied later in his Chicago laboratory. It is said that Chanute started the Wright brothers about this time on their career as the first birdmen. Unlike Langley, Chanute lived to share in the triumph of the Wrights. During the now historic experiments of Orville Wright, three years ago at Fort Myer, Virginia, it was very gratifying to be able to renew acquaintance with Octave Chanute, and to hear him quickly revert to his early experiments on San Diego Bay. With characteristic impulsiveness he pointed to the soaring Wright biplane as resembling his old friend, the San Diego pelican. Had Chanute lived to see

Glenn Curtiss' hydro-aëroplane, first navigated in San Diego air and water, the similitude to the pelican would have been even greater.

SAN DIEGO'S LOW WIND-MOVEMENT

Glenn Curtiss was likewise attracted to San Diego because of the absence of gusty winds and the dependability of the air in general. The United States Military Aviation School, directed by Mr. Curtiss, and located on North Island, the low-lying, brush-covered peninsula across San Diego Bay, has graduated half a hundred aviators since Mr. Curtiss installed his school in 1911. The proximity of the ocean on one side, and the quiet waters of the bay on the other, makes the location ideal for both his aëroplanes and hydro-aëroplanes.

TABLE XII.—*Average Wind in Miles Per Hour (1873-1911)*

By Months

January	4.9	July	5.8
February	5.6	August	5.6
March	6.1	September	5.6
April	6.3	October	5.1
May	6.3	November	5.1
June	6.0	December	4.9
Year	5.6		

By Hours

1 A.M.	3.6	1 P.M.	9.6
2 A.M.	3.7	2 P.M.	9.9
3 A.M.	3.7	3 P.M.	9.7
4 A.M.	3.7	4 P.M.	9.0
5 A.M.	3.8	5 P.M.	7.9
6 A.M.	3.8	6 P.M.	6.4
7 A.M.	3.8	7 P.M.	5.1
8 A.M.	3.9	8 P.M.	4.3
9 A.M.	4.5	9 P.M.	3.8
10 A.M.	5.9	10 P.M.	3.5
11 A.M.	7.4	11 P.M.	3.5
Noon	8.7	Midnight	3.6

The records of annual hourly wind-velocity show that the daylight winds, that is between seven in the morning and six at night, average 7.2 miles an hour. Night winds, between seven at night and six in the morning, average 3.8 miles an hour. The average time of the highest velocity is two o'clock in the afternoon when an annual average of 9.9 miles is recorded. The least wind is 3.5 miles an hour and is registered between ten and eleven at night. It was during that time of the day that the record of amateur monoplane flights was made to Tia Juana, Mexico, and return, in 1911. In morning flights it is important that the course should be over the level country and away from debouching valleys and uplifting headlands. It is during the first few hours after sunrise that the valley breeze begins. This is only the heavy, colder air obeying the impulse of gravity and seeking lower levels. The flow caused by differing densities of air may be observed almost any morning over the Bay of San Diego by watching smoke-columns. In a valley the wind is stronger in the center than on either side, for the same reason that the current in the middle of a stream of water is stronger, for there it has lost the friction of the banks. Knowledge of this fact allows the aviator to fly up a broad ravine, taking a central course. On the way down, however, the speed of the aëroplane must be increased.

In a recently published work on charts of the atmosphere, it would appear that if we are ever to take advantage of prevailing air-drifts from this country to Asia, the voyage could best be started from San Diego. The trip from Asia to America would be *via* a northern route.

CHAPTER XV

THE MIRAGE, HALO, AND AURORA

AMONG the infrequent meteorological phenomena that have been observed in San Diego are mirages, lunar and solar coronas, halos, and the aurora borealis. It is indicative of the wide variety in the climatic features of this locality that these optical and electric phenomena, which are typical of the desert and northern latitudes, have all been noted at the San Diego Weather Bureau office.

The mirage, that most elusive and bewildering fantasy of light and air, can be observed many times a year in San Diego. The common appearance of the mirage in this vicinity is the distortion and frequent inversion of distant objects over the bay and ocean. The Coronado Islands, for example, often seem to elongate and crumple up, volcanic cones and spires appearing where none exist. Portions of these islands seem to dissolve into thin air, and sometimes they, as well as ships appearing in the vicinity, are inverted. The mirage is simply a distorted or shifted, or both distorted and shifted, image of real objects that may be observed through field-glasses of high power, or even photographed. When the weather conditions are favorable, such as during a a quiet morning on the bay, vessels at anchor, or the Coronado ferry may be seen apparently to leave the water so that the opposite shore may be seen underneath. The tricks and fancies thus produced may well excite the credulous. A brief definition of

mirage is that it is an image produced by successive bending of rays of light passing through air-strata of varying densities.

CAUSE OF SOLAR AND LUNAR HALOS

Rings around the sun or moon, mock suns or moons, are always a source of interest and, to some, of needless apprehension. We see fewer halos in San Diego than in colder or more stormy latitudes. The records show that solar and lunar halos average six or seven, respectively, in the year, and that they invariably occur from October to April. The greatest number of halos occurring in any one year in San Diego was fifty-eight in 1885. While halos possess no special significance, and are classed with rainbows and other optical phenomena, their structure and classification is not without interest to a student of local climatology. Two kinds of rings about the sun and moon are sometimes seen in San Diego; whether they are halos or simple coronas depends on the diameter of the rings. A corona is always observed when the sun or moon is shining through moderately thin clouds, and this circle has a radius of from 4 to 8 degrees, with prismatic colors, the blue nearest the source of light. Halos, in their commonest form, have a radius of about 22 degrees, often with brilliant prismatic colors, with the red nearest the sun or moon. Halos are caused by the action of sunlight or moonlight on ice-needles in thin *cirrus* clouds. In falling to earth these minute crystals of ice assume a horizontal position, owing to their structure and rapid rotation. The effect of light on these spiculæ is to produce halos of differing

degrees of brilliancy. When observed near the horizon these circles often intersect with secondary circles, and points of intersection thus become very bright and form mock suns or mock moons. These are sometimes called "sun dogs" or "moon dogs." It is not often, however, that the humidity above San Diego is sufficient and well enough distributed to produce such phenomena.

THE AURORA BOREALIS HAS BEEN SEEN THREE TIMES IN SAN DIEGO

The aurora borealis, "northern lights," or "merry dancers," has been observed three times in San Diego in over forty years. Recent investigations show that the aurora can hardly be classed as a meteorological feature. It is a manifestation of atmospheric electricity, possibly resulting from a bombardment of the atmosphere by particles projected at great velocities from the sun. The aurora has been seen so infrequently as far south as this latitude that a description of the auroras of thirty years ago may be interesting. The daily journal of the Weather Bureau of 1882 has these entries:

> *November 17.—The first appearance of the aurora was two columns, or shafts, of light which shot up from the northern horizon to about 20 degrees. The completion of the arch was not visible, but the columns blended together forming a cloud, or floating mass, of deep rose-color. This varied in intensity until 7.30 p.m., when it passed from view. This is the first aurora ever recorded in San Diego.*
>
> *November 19.—Fair aurora of two luminous beams rising to about 20 degrees and then separated. The space*

Hamilton's flight over Point Loma

1. Mercurial barometer.
2. Barograph (recording barometer).
3. Thermograph (recording thermometer).
4. Maximum thermometer.
5. Minimum thermometer.
6. Tele-thermoscope (electric thermometer).
7. Whirled psychrometer
8. Marine hygrometer.
9. Hygrograph.
10. Sling psychrometer.
11. Photographic sunshine recorder.
12. Electric sunshine recorder.
13. Metrograph, recording sunshine, rain, wind direction and velocity.
14. Anemometer.
15. Anemoscope.
16. Rain-gage.
17. Recording rain-gage.
18. Rain-measuring cup.

Meteorological instruments in use at the local office of the United States Weather Bureau at San Diego

between the tops of the columns was of a pale yellow. The phenomenon lasted from 4.20 a.m. until daylight.

February 3, 1888.—From 3.10 a.m. to 5 a.m. an aurora was visible in the north and west. The base was shot with green bands above and rose-color below. The colors were not very bright.

These three are the only auroras ever witnessed in San Diego.

CHAPTER XVI

THUNDERSTORMS AND OTHER RARE WEATHER CONDITIONS

SINCE the establishment of the local Weather Bureau office in 1871, San Diego has experienced sixty-seven thunderstorms, thus averaging a little less than two each year. Thunderstorms and attendant weather phenomena have always been recorded and studied in detail, so that each one of these storms has its own particular history written in the government records. The subject is an interesting one, both on account of the infrequency of these local storms and the individuality of their record.

Thunderstorms, like all other kinds of weather, are caused by the great aërial eddies of the atmosphere modified by local conditions. If we examine the daily weather map, we shall find that thunderstorms in southern California generally occur in the southwestern quadrant of a region of low barometer.

TABLE XIII.—*Distribution of Thunderstorms by Months and Hours. (Total number in forty years)*

	Day	Night		Day	Night
January	3	1	August	3	7
February	3	4	September	2	3
March	7	6	October	3	3
April	3	2	November	0	0
May	1	4	December	2	2
June	0	1		—	—
July	2	5	Year	29	38
Total				67	

"Day" and "night" are approximately sunrise to sunset and sunset to sunrise.

Distribution by Hours in the Twenty-four

1 A.M.	2	1 P.M.	0
2 A.M.	1	2 P.M.	3
3 A.M.	5	3 P.M.	4
4 A.M.	2	4 P.M.	2
5 A.M.	2	5 P.M.	3
6 A.M.	1	6 P.M.	2
7 A.M.	2	7 P.M.	5
8 A.M.	3	8 P.M.	6
9 A.M.	7	9 P.M.	4
10 A.M.	5	10 P.M.	2
11 A.M.	0	11 P.M.	4
Noon	0	Midnight	2
Total	30	Total	37

These tables show that thirty-eight out of a total of sixty-seven thunderstorms recorded in San Diego in the past forty years occurred during the hours after sunset; more occurred in August than in any one month of the year; none have been observed in November and only one in June. There appear to be two periods of thunderstorm frequency in the twenty-four hours—nine in the morning and eight in the even ng.

TWO WATERSPOUTS HAVE BEEN SEEN IN SAN DIEGO

As waterspouts occur only during thunderstorm weather, they are generally classed as attendant phenomena. Two waterspouts have been observed in San Diego—the first one on December 9, 1898, and the other on March 11, 1909.

As both of the waterspouts observed in San Diego were similar in general formation, and presented the usual features common to such phenomena, they will be described together. A few miles off Point Loma a gray mass of *nimbus* cloud overhung the moderate swell of the sea, and from this cloud could

be seen several convex projections. They would extend downward as wisps of cloud; they would withdraw quickly until one dropped suddenly to the sea and showed a slightly inclined column of whitish vapor. The waterspouts were 1,000 to 1,500 feet high, and from 100 to 125 feet in diameter. The sheath of vapor moved against the wind, traversing the six or eight miles of their course in ten or twelve minutes. There are evidences that the waterspout of 1898 moved inland for a few thousand yards, causing heavy downpours which washed out patches of vegetation, leaving the bare rock exposed in considerable areas. The southern slope of Mount Soledad shows such barren places.

CHAPTER XVII

THE PHENOMENON OF FROST

THE month of December, 1911, will go down in the meteorological history of California as one of the frostiest on record. It was the coldest but one in the past fifty years of temperature observations at San Diego. The average daily temperature in December was 53 degrees, and this was the lowest for the last two decades. The number of light and heavy frosts broke all previous records. There were no killing frosts in this vicinity, and none have ever occurred in the history of San Diego.

As frost in San Diego is a phenomenon, it appears worth while to consider its cause and why this region is comparatively free from its injury.

Horticulturists have decided that plant-growth is at a standstill when the daily mean temperature is 43 degrees, or lower. Or, in other words, when the average twenty-hours' temperature is above 43 degrees, plants are growing. Under this criterion the mean daily temperature records of San Diego show that for forty years (or 15,000 days) there were six days when the mean temperature equalled or dropped below 43 degrees. All of these days occurred in January of 1880, 1882, 1888, and 1894. Putting it in another way, we may say that since the beginning of temperature observations, which cover a period of 15,000 days, there were 14,994 days of growing weather.

FROST A MATTER OF AIR-DRAINAGE

Cold air is denser than warm air, and air, like water, seeks its level. It is thus seen why the temperature of low-lying districts is very much lower than that of the mesas, benches, or terraces. Advantage is taken of this fact by the orchardists, who plant lemon and orange trees on the terraces, while the olive and hardier trees skirt the hillsides. The formation of frost is thus seen to be largely a matter of air-drainage, for frost usually forms first in pools or basins.

WHY SAN DIEGO HAS NEVER HAD A KILLING FROST

In the standard "Climatology of the United States," issued by the central office of the United States Weather Bureau, appears this statement on page 28:

> *The absolute minimum temperature at San Diego, California, is 32 degrees, and at Key West, Florida, 41 degrees. These are the only Weather Bureau stations in the United States where a minimum temperature below freezing has not been experienced.*

The reason why San Diego has never experienced a killing frost is because the ocean, over which blows 75 per cent of San Diego's winds, has a temperature many degrees higher than the land. For example: Shortly before sunrise, at the time of the lowest temperature (36 degrees on December 26, 1911), the temperature of the ocean was 59 degrees, or 23 degrees warmer than the land. The warm air from the ocean is transported over the land, raising the temperature above the danger point.

CHAPTER XVIII

THE INTER-RELATION BETWEEN OCEAN CURRENTS AND WEATHER CONDITIONS

IT has frequently been claimed that the Japan Current controls the weather of the Pacific Coast, and, on the other hand, quite as often asserted that it has not the slightest influence on the climate of this region. Both statements need qualification, for there is a complex inter-relation between ocean currents and weather conditions, not only on our own Pacific Coast, but everywhere all over the earth.

The following brief account of this inter-relation, by Prof. W. J. Humphreys, of the United States Weather Bureau, is offered as an aid to a clearer understanding of this much-mooted subject:

"There are many things that contribute to the general circulation of the waters of the earth, but the principal cause of ocean currents is the driving force of the prevailing winds of the globe. Within the tropics, for instance, the surface wind is usually from the east, and this, in the course of many years, has established an equatorial drift of warm water from east to west across all the great oceans of that region. But the drift is interrupted and deflected by chains of islands and by the coasts of continents, and still further influenced in its course by the rotation of the earth which, in general, causes warm currents, or those that flow toward higher latitudes, to turn eastward, and cold currents, or those that flow toward the equator, to turn westward.

"In this way the equatorial drift of the Pacific Ocean, that flows around and among the Philippine Islands, merges into the Japan Current, which, partly by the deflection of the coast of China and partly under the influence of the rotation of the earth, turns to the northeast, where it is further impelled along its course by the west winds of the North Pacific. After crossing the ocean from west to east, the waters gradually turn south, and eventually merge with and once more become a part of the equatorial drift.

"In the same way, the equatorial Atlantic drift and the Gulf Stream are but separate portions of a continuous circulation.

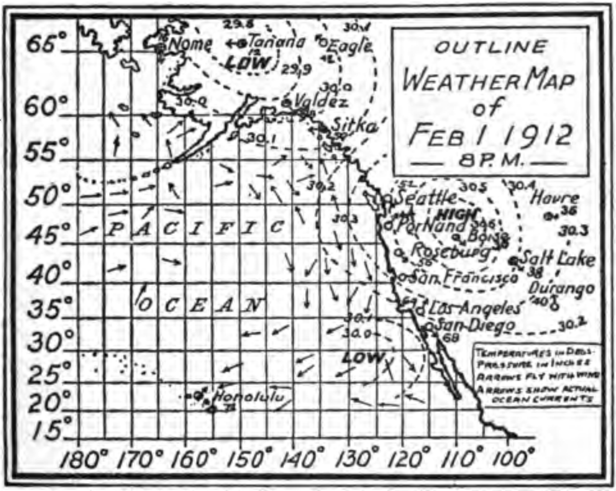
"The chief cause, therefore, of the ocean currents is persistent or prevailing winds; but the existing system of currents, their number, location, and direction, is, in great measure, determined by the rotation of the earth and by the position and extent of interfering and deflecting islands and continents.

"Let us see now what effects, if any, ocean currents can have upon the winds of the globe that keep them in motion, and what modifications the currents therefore must make of the climate and weather of the regions over which these winds themselves ultimately pass.

"It is well known, and the reason is obvious, that the surface temperature of the ocean and the temperature of the atmosphere that for some time has been in contact with it are nearly the same. Hence any change in the temperature of the ocean surface changes approximately to the same extent the temperature of the winds that blow over it, and thus

indirectly the temperature of the lands over which they immediately pass.

"In so far, therefore, as the surface temperature of the North Pacific, for instance, is warmer because of the Japan Current than it would be if no such cur-



Outline weather map, (extended to show weather conditions) at 8 P.M., February 1, 1912

rent existed, approximately to that same extent are the on-shore winds of Alaska, British Columbia, and our own west coast warmer, and also more humid than they would otherwise be. But just how much warmer the surface of the North Pacific Ocean is because of the Japan Current, or the surface of the North Atlantic Ocean because of the Gulf

Stream, no one knows at all accurately—it may be quite as much as 5° Fahr. in each case. At any rate, it certainly is not negligible in amount, and therefore warm ocean currents, through the winds they have tempered, undoubtedly modify the climates of certain favorably situated islands and coasts.

"It must not be supposed, however, that warm and cold ocean currents are the chief causes of the climatic difference between Labrador and Ireland, for instance, or Labrador and southern Alaska, for such indeed is not the case. Here the extreme temperatures of Labrador are caused by the passage of its prevailing wind over the surface of a continent which itself is subject to wide temperature changes, while, on the other hand, the equable climate of Ireland, say, is due to the fact that its prevailing winds come from over the ocean, whose temperature, because of its great heat-capacity and mobile surface, changes but little from month to month and from year to year. This explains the chief cause of the difference between the two types of climates, the marine or equable, and the continental or extreme. But, as already explained, the temperature of the ocean surface itself is dependent in part upon the ocean currents, and, therefore, in this way they become factors in the production of the weather and climate of many places, though how great their influence it is impossible, as already stated, accurately to estimate.

"In addition to the above, there is another and even greater influence of ocean currents on climate and weather, indirectly effected through the formation and location of permanent 'highs.'

"By a process perfectly well known, the explanation of which would be out of place here, because necessarily tedious and elaborate, the east winds of the tropics and the west winds of the higher latitudes conspire to produce two belts of high barometric pressure practically parallel to the equator, situated at, roughly, 30 degrees north to 35 degrees south, respectively.

"If now these belts were of uniform pressure throughout they obviously would divide the earth into three great zones, each with its own circulation and with a radically altered, and probably much reduced, atmospheric interchange the one with another. But, instead of being uniform, they have sub-permanent high centers, each of which leads to a vigorous circulation from zone to zone that profoundly modifies the direction of the prevailing winds, and hence the weather and the climate in its neighborhood. And this is of distinct importance to San Diego, since one of these centers lies just off the coast of southern California.

"Now each permanent ocean 'high' is at that place where a cold ocean current crosses a belt of high pressure. It is there because at this place the planetary winds, as above explained, and the cooling effect of the cold current both tend to produce a high barometer, and therefore together lead to a greater pressure than either alone could produce, or than either alone at other places actually does produce.

"The conclusion, therefore, is that ocean currents, partly through their influence on the temperature and humidity of the atmosphere, but especially through their influence in determining the existence

and fixing the position of permanent ocean 'highs,' though seldom, if ever, the chief factor, do distinctly modify the weather and the climate of many parts of the earth.

"In short, the entire circulation of the atmosphere and of the ocean and the distribution of temperature, humidity, and rainfall are so intimately woven together into one complex interdependent whole that no change could be made in any one without producing a reaction upon all the others."

CHAPTER XIX

METEOROLOGICAL MYTHS

METEOROLOGY has the unusual distinction of being the oldest as well as the youngest of the natural sciences. Hieroglyphic inscriptions record the weather conditions prevailing in the valley of the Nile 6,000 years ago. These, and succeeding records, extending through Bible times, and the intervening centuries up to within the past fifty years, were matters of only individual observation. It remained for the new science of meteorology to correlate these isolated facts. With the beginning of simultaneous weather observations in different parts of the country the new meteorology had its birth. In the centuries that have elapsed it is not strange that changes in weather have been ascribed to many fanciful sources. The variety of meteorological myths is limited only by the credulity of man.

San Diego, as a locality, is remarkably free from many of the popular misconceptions of the weather that are still firmly believed in other communities. The reason is undoubtedly because of the equability of the climate and the close attention given weather conditions. The infrequent stormy periods in San Diego upset all preconceived notions as to "equinoctial storms" and the influence of the moon on the weather. Even the time-honored almanac, with its weather-changes for every day of the year, is neglected. It is frequently remarked: "I could tell something about the weather back east, but out

here in California things are different." Really the only difference is that in other less regular climates the changes are so rapid that it is an easy matter to make almost any assumption fit. Then, too, coincidences are remembered, while a large number of failures to coincide are forgotten. The limitations of this chapter make it necessary to mention only a few of the more prevalent weather myths, and to give some reasons why these time-honored beliefs should be classified as superstitions.

EQUINOCTIAL STORMS ARE UNKNOWN IN SAN DIEGO OR ELSEWHERE

The "equinoctial storm" is a myth that is not difficult to dispel in this locality; but, in regions where storms are frequent, there are generally a sufficient number of disturbances during the latter part of September or March to verify any prediction, provided always that sufficient leeway is given for verification. The equinoctial period is only an incident in the annual history of the earth when the days and nights are of equal length. It has not been explained by the adherents of the "equinoctial storm" theory why wind, rain, or snow should more frequently occur on the exact date the sun crosses the plane of the earth's equator than during other days of those months. A rigid examination of weather records at San Diego and other stations proves that storms do not occur more frequently on the 21st of September or the 21st of March than on other arbitrary dates.

THE MOON DOES NOT INFLUENCE THE WEATHER

The moon does not influence the weather, but it does indirectly lengthen the day. The influence of the tides retards the earth's rotary motion which causes it to slow up very gradually; in fact *the day is lengthened one-quarter of a second in 3,600 years.* Many persons give credence to the control of the weather by the moon, but examination of the reason for their faith does not disclose any scientific foundation. The astronomer Herschel was the last scientist of repute to father lunar control of the earth's weather; but his theory was abandoned after a study of weather statistics during different phases of the moon. Out of the innumerable combinations in which the moon figures there is space to consider but one: "If the points of the new moon are turned up, the weather will be dry; if turned down, it will be wet." Another version of the proverb is that it will be dry if the upturned points allow the legendary Indian to hang up his powder horn. Is it not strange, even in the absence of data to verify either one or the other of these contradictory statements, that this superstition should linger, when a little reasoning would show that such an aspect of the moon would be the same for all places on the same circle of latitude? If the inclination of the horns of the moon affected the weather, then the weather would be the same, for example, from southern California to South Carolina. We know that this is not the case, for, following San Diego's 32-degree belt eastward to Charleston, widely diverse climates are encountered. We have the dry climate of the elevated plateaus of Arizona and New Mexico and the

plains of Texas, the changeable weather of Oklahoma, the frequent storms of Louisiana, Arkansas, Mississippi, and Alabama, and the south Atlantic rains of the coasts of Georgia and South Carolina. The old adage says:

The moon and the weather
May change together,
But change of the moon
Does not change the weather.

Nothing is so mechanical as the moon, nothing is so uncertain as the weather, and yet the myth of lunar control of weather conditions has persisted for centuries, and will doubtless be credited in centuries to come. The explanation is a working out of a psychological instead of a physical law. Did not Fisher explain it when he said:

> *There is no consciousness, on the part of those from whom the myth emanates, that this product of their fancy and feeling is fictitious. From the myth the element of deliberation is utterly absent. There is no questioning of its reality, no criticism or inquiry on the point, but the most simple unreasoning faith."*

ALMANAC WEATHER PREDICTIONS HAVE BEEN UNCHANGED FOR A CENTURY

History records that the almanac's so-called daily weather predictions for years in advance had its origin among the Greeks, and in this manner: For popular use they posted daily weather conditions as they occurred; wind, rain, and cloud were carefully noted, and later they added the rising and setting of the stars to indicate time. Consequently,

the weather and stars were afterwards erroneously associated together. We have in San Diego a local parallel of the publication in the daily newspapers of the weather report in the same column with the tide table, leading many persons to believe that from this simple accident of proximity there is a relationship between them. In the days of Greece an endeavor was made to correct the association of the accurate almanac record of the stars with the weather conditions, but the superstition steadily gained in popularity until it became an accepted fact. According to Hellmann, one of the ancient warnings was uttered by Gemenius two thousand years ago:

> *Concerning the teachings of weather phenomena, there is a prevalent and erroneous superstition that atmospheric phenomena depend on the rising and setting of the stars. Mathematics and natural history teach a totally different conception.*

The attractive myth grew, however, until it became incorporated into the life of the people. This superstition is prevalent even today in many parts of the country, and the fiction of the weather is accepted with the facts of the astronomical information. Time has not changed the character or the scope of these so-called weather predictions. The author has a collection of original Farmer's Almanacs published in Boston a century ago, and it is interesting to note in comparison with the latest patent-medicine almanac that the so-called predictions and their phraseology are identical.

CHAPTER XX

MARINE METEOROLOGY IN SAN DIEGO

THE first person to make meteorological observations in the vicinity of San Diego was Captain Juan Rodriguez Cabrillo, when, with his frail caravels, the "San Salvador" and "Victoria," in September, 1542, he entered the Bay of San Diego. Maps and instruments were very crude 370 years ago, and navigation had none of the safeguards that science has since given it. The sea was then a trackless waste, abounding in hidden perils of unknown currents and winds. History does not show much advance in the science of marine meteorology until the last fifty years. Benjamin Franklin, on his homeward voyage from England in 1739, kept records of the weather and water temperatures, using an English Fahrenheit thermometer, and suggested a method of determining the approach of vessels to the American coast by the temperature of the water. Thus the brilliant Franklin was the first American to make suggestions as to the utility of marine meteorological observations.

It remained for another American, Lieut. M. F. Maury, author of that picturesque and highly interesting "Physical Geography of the Sea," to be the first to interest a nation in the publication of sailing charts based on the data collected from ships' logs. Until the beginning of the Civil War terminated his career as a United States naval officer, Maury was successful as a hydrographer,

founding that Bureau of the Navy. The Navy collected the data and published meteorological charts until about six years ago, when an exchange of duties was arranged between the Navy and the Weather Bureau. The latter turned over to the Navy its system of wireless telegraphy in exchange for the marine meteorological work. Rear Admiral H. N. Manney, U.S.N., retired, now a resident of San Diego, was a member of the presidential committee that arranged the exchange.

SAN DIEGO IS ONE OF THE EIGHTEEN MARINE CENTERS IN THE UNITED STATES

There are eighteen stations of the Weather Bureau designated as "Marine Centers" where ocean reports are collected, compiled, and afterwards forwarded to the central office of the Weather Bureau at Washington. San Diego was among the first of such stations to be established. A majority of all the vessels sailing the seas take a simultaneous observation of meteorological instruments at Greenwich noon, and it is entered on special forms furnished by the United States Weather Bureau. Supplementing this noon observation, readings of the barometer and thermometer are made hourly by all the war vessels of the different countries, and the merchant ships make a record of such conditions every four hours. The Weather Bureau has, in all, about 3,000 observers of every nationality, and from these reports prepares daily synoptic charts of meteorological data, thus being enabled to plot the weather conditions prevailing over the oceans from day to day for the purpose of tracing storm-

tracks, percentages of fog, prevailing direction of wind, trade-wind limits, pressure, and temperature.

WORLD METEOROLOGY ADVANCING BY COÖPERATION OF SHIPMASTERS

Mariners who coöperate in this work are serving their own interests, as the compiled results of their observations are returned to them free of cost on the meteorological charts. In the early days of marine meteorology, much of the data was buried in official files; but now, under modern office methods, every item of accurate information is used. The result of this work is greater safety on the seas, increased efficiency in navigation, and economy of time and power. By charting great-circle sailing routes, so as to take advantage of favoring winds, time is saved in sailing vessels and fuel in steamships. These are some of the practical gains to commerce. The impetus given to meteorology by enlisting the services of shipmasters throughout the world considerably advances this science. While the deductions made from marine meteorological observations have frequently been of a negative nature, such work has, nevertheless, laid the foundation for a future treatment of the meteorology of the earth as a whole that will be both consistent and comprehensive.

CHAPTER XXI

FORECASTING SAN DIEGO WEATHER

FEBRUARY and March of 1912 in San Diego were remarkable months as regards deficient and excessive rainfall. In the former no rain fell, and in the latter there were more rainy days than ever before experienced in any month since the record began. Notwithstanding the phenomenally large number of rainy days in March, the Weather Bureau correctly forecast the twenty rainy days as well as the eleven fair days. In considering the actual atmospheric conditions which then prevailed, a study of the conditions during these record-breaking months, including both fair and stormy weather, can be gained only by examining the weather map. Until the weather map was introduced (which was less than a generation ago), correct weather forecasts were impossible. The weather map is practically an instantaneous photograph of the state of the weather at the hours of observation.

HOW THE WEATHER MAP IS MADE

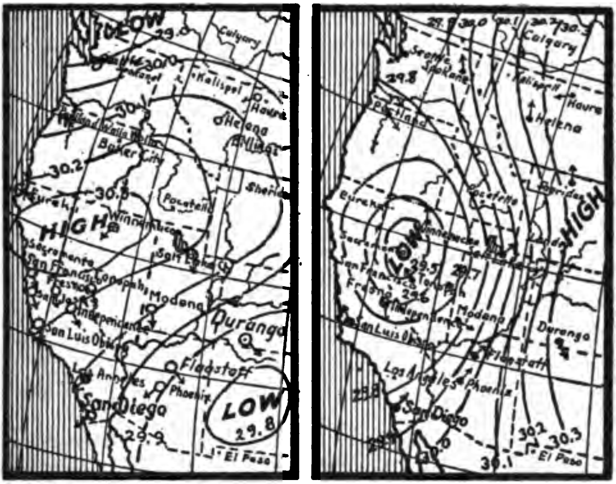
Scattered over the United States are some 200 weather stations which send simultaneous observations of barometric pressure, temperature, rainfall, wind direction and velocity. These observations are made at 8 A.M. and 8 P.M. 75th meridian time, or 5 A.M. and 5 P.M. Pacific time. The system of observation and transmission has been so perfected that

within thirty minutes complete returns from all portions of the United States have been received in Washington and exchanges made in all of the larger cities. The San Diego station receives both morning and evening reports, but the morning map only is published and used in forecasting. As rapidly as the reports, which are in cipher, are received, they are translated and entered on the map. Lines are drawn connecting regions of equal barometric pressure, the wind is indicated by arrows, the character of the weather (fair, cloudy, etc.) is shown by symbols, the rain by shaded portions and the temperatures by dotted lines. The result gives a map like the specimen shown in the accompanying illustration.

THE PASSAGE OF "HIGHS" AND "LOWS" CONTROLS WEATHER CONDITIONS

The words "high" and "low" refer to the barometer and indicate that it is relatively high or low. Pressure in this instance is not force—a high pressure area, for example, is simply a region which has a higher barometric value than the surrounding region. Both of these eddies move along with the general drift of the air, but the movement within these eddies has a spiral tendency. The wind is outward and downward in a "high," and inward and upward in a "low." The weather, during the winter, is dry and cool when a "high" area controls, and relatively moist and warm when a "low" area prevails, but, so far as temperature is concerned, generally the reverse during summer. Another interesting feature of these barometric pressure

areas is that, owing to their circular character, stations hundreds of miles to the east of San Diego are invaluable for forecasting. Owing to the round or oval shape of barometric areas, reports from



Fair-weather type **Rain type**

Actual weather maps of 8 A.M., February 15, 1912, and 8 A.M., March 1, 1912. Atmospheric pressure in inches. Wind direction shown by arrows.

Winnemucca, Nevada, and Flagstaff, Arizona, frequently show the shape and depth of a depression whose southwestern limits are hundreds of miles at sea off the coast of southern California.

The map of February 15, 1912, is a type common to fair weather for the reason that the high area prevails more than two-thirds of the time. In this

chart the wind will be noted as blowing outward from the center of the high, and that to the southward the skies are clear and there is absence of rain. On the contrary, the map of March 1 is distinctly a rain type. Warm and humid winds are blowing into the center of the low area, and the high area to the eastward blocks the further drift of the low.

Rainfall is the most difficult weather feature to predict; wind is readily forecast, for, after locating the low and high areas, the direction and velocity of the wind cease to be matters of conjecture. The winds in a low area always blow spirally in a direction opposite to the hands of a watch; in a high area spirally outward in the opposite direction. The velocity of the wind depends on the barometric gradient—that is, if the lines of barometric pressure are close together on the map, the winds will be proportionately brisk. Temperature changes are predicted by remembering that the wind preceding and attending a "low" is warm, and in a "high," cool.

Weather forecasting would be comparatively easy if these whirling air-masses traveled across the country at a regular rate, but often they have a disconcerting way of stopping en route on their eastern journey. Sometimes the procession of high and low areas will move in an orderly manner like beads on a string, but more frequently a well-defined area will dissipate in the upper air levels or an insignificent low area will deepen and spread out until it covers the greater part of the United States.

These explanations will show why the Weather Bureau makes no attempt to forecast the weather from local conditions at any particular station, and

that it bases its forecasts upon the weather prevailing over a large extent of territory as shown by the regular telegraphic reports. The forecasters of the Weather Bureau have no secrets, for they share the results of their study and investigations with a generally interested public.

CHAPTER XXII

LOCAL WEATHER SIGNS

SAN DIEGO is an ideal place to study meteorology—even without instruments. The sea, the mountains, the plateaus and the desert are within reach of the vision, and the effect of the ocean of air over these physical configurations of the earth can be studied hourly and daily, and from month to month, producing a moving picture of atmospheric conditions that will interest all who pause and study it. We have only to lift our eyes to see the glory and majesty of nature displayed in this region with a lavish variety.

While instruments and instructions are necessary for accurate results, the science of meteorology can be studied to a certain extent without books or instruments, the only requisites being an accurate eye, a quick ear, and clear discernment between cause and effect. Nature yields her secrets most readily to the patient and painstaking observer.

FORETELLING THE WEATHER WITHOUT INSTRUMENTS

Every region has its local weather signs from which much can be learned by watching the sky as to existing and approaching meteorological changes. All weather conditions concern the air, and these may be divided into five classes: Those relating to the temperature of the air as felt by the human body; the movement of the air which includes the varying wind direction and velocity; the moist-

ure in the air, as exhibited by clouds; rings around the sun and moon; falling smoke and kindred phenomena, and the homogeneity of the air, which allows clear vision and good hearing.

CLOUDS ARE THE BEST GUIDES OF LOCAL WEATHER CHANGES

Of all natural phenomena the clouds are the best indicators of the weather. Observations of their structure, height, and direction are excellent guides to weather changes. In San Diego it is sometimes difficult for the beginner to determine whether the clouds are of the rain-making or of the sun-shade variety: if the cloud is not well defined and the islands and mountains can be seen underneath, then the *velo* cloud is in evidence and it may be expected to dissipate in the morning. If above the lower cloud are seen glimpses of an upper and lighter covering, then the sky is threatening and especially so if the upper clouds have a southerly direction. Experience shows that the direction of the upper clouds eventually becomes that of the surface wind direction. It is an indication of rain if the wisps, tips, and ragged edges of the clouds trend upwards and incline from south to north, for they thus mark the ascending air movement which always precedes rain. If the clouds change from a lower to a higher level, fair weather is assured.

A cloud-cap over Otay mountain or San Miguel peak is a precursor of rain. Clouds of great height are disclosed by the mistiness of the stars and rings about the sun or moon. The proverb

Rainbow in morning, sailors take warning;
Rainbow at night, sailors' delight

is true because the rainbow in the morning is in the western sky, from which direction storms normally move. In the evening the rainbow is in the east, as evidence that the rainstorm has passed the observer.

SAID PRAYERS FOR RAIN ONLY WHEN SOUTH WIND PREVAILED

It was San Diego's best-loved priest, the late Father Ubach, who refused to offer prayers for rain unless the wind stayed in the south for three days. The good father was a keen student of the weather, as frequent conversations with him attested. Winds precede rain when they blow either steadily from the south, or in gusts from the east. Northerly progression of wave-crests is another manifestation of coming storms, as are also wild ducks and geese flying south after the first northern storm. Wild birds always use the storm winds and are borne at great speed to the south by taking advantage of the spiral winds in a storm center.

WHY INCREASED AUDIBILITY AND VISIBILITY ARE PROGNOSTICS OF RAIN

A San Diego physician says that he can always foretell rain when he hears the rumble of the Santa Fe trains at night, or sees the cañons on the Coronado islands by day. This is true, for local rainstorms are frequently preceded by increased audibility of sounds at night, such as the rumble of trains, whistling buoys, church bells, etc., and in the day-

time distinct objects appear much nearer because the air then has a uniform distribution of temperature and moisture. Normal air at sea-level is a mixture of warm and cold currents of varying humidities, which, through irregular refraction and reflection, obstruct to a considerable degree both light and sound.

CHAPTER XXIII

METEOROLOGICAL INSTRUMENTS

IT is not generally known that one of the most valuable weather-recording appliances now in use by most meteorological observatories of the world was invented by an army officer while on the San Diego-Yuma stage-coach forty years ago. While disposing of obsolete instruments in 1896, the writer found an old wind-register bearing a plate engraved "Anemograph No. 13, Invented by Lieutenant Gibbon, U. S. A." The plate was removed and sent as a souvenir to Major Gibbon, then living in Washington. In his acknowledgement he gave the interesting information that he invented the anemograph in the early seventies, while taking the tedious stage ride from San Diego to Yuma. Thus San Diego is closely associated with the first automatic wind-register. The Gibbon anemograph has since been superseded by more intricate automatic instruments, but the principle of the early pattern, consisting of a drum on a spiral shaft actuated by clockwork, remains unchanged, and has been a unique feature in this model of chronograph. The local station of the United States Weather Bureau has, from its establishment, been an early recipient of the most approved meteorological instruments, as they were issued from Washington. Continuous automatic registration is maintained of atmospheric pressure, temperature, humidity, wind velocity and direction, sunshine, and rain. Some idea of the weather-recording equipment may

be gained from the photograph facing page 63 which shows the apparatus in use at the local Weather Bureau station.

The most valuable instrument to meteorologists is the barometer, which measures the pressure of the air. There are two kinds of barometers, mercurial and aneroid, and both are used at the local station. The mercurial barometer is simply a glass tube sealed at one end and filled with mercury. The height of the mercury in the tube shows the weight of the air, so when we speak of the barometer reading 29.98 inches it is meant that the weight of the atmosphere is balanced by 29.98 inches of mercury. The aneroid barometer is used in the form of a barograph. The changing air-pressure contracts and expands a series of corrugated vacuum boxes and the motion is shown by means of a recording pen that traces the line on a revolving cylinder.

THERMOMETER LOCATED AT SAN DIEGO MISSION IN 1849

The temperature of the air is measured by several kinds of thermometers—mercurial, alcohol, and electric. Observations with mercurial thermometers were begun in San Diego in 1849 and continued without interruption to the present day. In 1872 an alcohol minimum thermometer (showing the lowest point reached) was installed in San Diego, together with a maximum thermometer which by means of a constriction near the bulb shows the highest point registered by the mercury. In 1892 continuous automatic records of temperature were begun by using a thermograph, which traces a line

on a cylinder turned by clockwork. All the thermometers are exposed on the roof some distance from the office rooms, and to enable the observer to answer inquiries more readily, an electric-telethermoscope was installed about three years ago. This instrument gives the temperature at a distance by means of electrical resistance coils and a galvanometer. Although there are seven varieties of thermometers in use, there is less than a degree's variation between them.

HOW HUMIDITY IS MEASURED

The humidity of the air was observed in 1871 by using two thermometers placed side by side, one with a bit of moistened wicking around the bulb. By means of tables, prepared from actual observations in the laboratory, the difference in temperature between the two thermometers showed the amount of moisture in the air. Eighteen years later an improved humidity apparatus called the whirled psychrometer was installed. By means of gears the thermometers were rapidly whirled, thus securing satisfactory ventilation. Since 1908 the humidity has been continuously recorded by means of a hair hygrograph. When the hair is damp it absorbs more moisture and increases in length; when the air becomes drier the moisture evaporates and the hair shortens. These variations in humidity are traced on a revolving cylinder similar to a thermograph. Since the installation of the hygrograph, a range in relative humidity from 2 to 100 per cent has been recorded, or from nearly absolute dryness to complete saturation of the air.

THE SUN MAKES ITS OWN RECORD

A small brass camera traced the sunshine on a piece of blue-print paper from 1880 until 1897, when an electric sunshine recorder was installed. This device constitutes an air, alcohol and mercurial thermometer in a vacuum tube, where two platinum wires are inserted. When the sun shines on the blackened thermometer bulb the air expands (the absorption is greater, thus increasing the expansion), forcing the mercury up to, and in contact with the platinum points. This completes the circuit and actuates an electrical marker in the office. The apparatus is so delicate that a passing cloud intercepting the sunlight for only a minute will be shown on the record sheet. During the solar eclipse of 1911, this recorder showed its exact duration in minutes.

The pattern of the rain-gage is so simple that it is very much doubted if its principle has materially changed since the first one was set up in the old San Diego churchyard, sixty years ago. A rain-gage consists of a brass funnel eight inches in diameter with a two-inch flange. The rain falling into this funnel passes into a tube 2.56 inches in diameter which therefore has an area one-tenth that of the funnel. To measure the rain, a small, thin cedar stick marked off in tenths of inches is dropped into the tube, and the depth to which the stick is moistened shows the rain in inches and hundredths. A simple recording float rain-gage was installed in San Diego in 1891, but this was replaced by the present style of tipping bucket in 1898. The tipping bucket is a small and perfectly balanced receptacle

divided into two compartments, each holding one-hundredth of an inch of rain. When one side of the bucket fills it overbalances and completes an electric circuit recording the amount on a register in the office.

An anemometer consisting of four hollow hemispheric metallic cups revolving on a vertical axis has recorded every mile of wind in San Diego since 1871. The cups of the anemometer approximate 500 revolutions to the mile of wind.

The direction of the wind has been traced each minute by means of a delicately balanced wind-vane for nearly twenty years. The changes in the direction of the wind, every mile of wind movement, every hundredth of an inch of rain, and every minute of sunshine are automatically inscribed in the office on an instrument called the metrograph. This is the latest improvement of the original Gibbon wind-register. All of these important atmospheric elements are accurately traced in different-colored inks at the exact time of their occurrence. The wind, rain, and sunshine are marked in parallel columns so that even a beginner may see in a graphic manner the relationship between these elements. The rainfall is registered by indentations, wind direction is dotted, wind velocity is shown by offset marks, and the sunshine is clicked off in regular "upstairs and downstairs" tracings.

CHAPTER XXIV

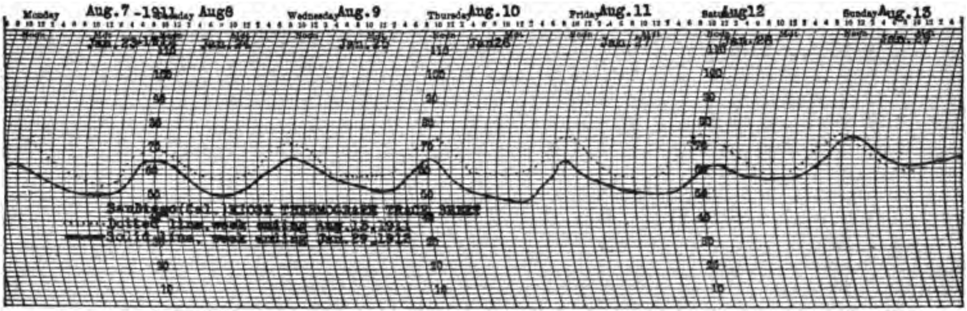
THE WEATHER KIOSK IN THE PLAZA

WHEN in the city of Washington a few summers ago, the writer noticed what appeared to be a miniature Greek temple on the spacious grounds of the United States Weather Bureau. On inquiry it was found to be an artistic street instrument-shelter designed to give the populace of large cities easy access to weather information. This structure was of enameled white cast-iron with four plate-glass sides permitting views of meteorological instruments, weather bulletins, charts, etc. It was explained by the Washington officials that should the preliminary tryout prove satisfactory it was the intention to supply the larger cities of the country with such structures. This street instrument-shelter was called a "kiosk." Kiosk is a Turkish word meaning a pavilion, and is sometimes spelled "kiosque." It is pronounced with the accent on the last syllable and the "i" short, as in "it." The visiting Californian was impressed with the utility and beauty of the kiosk, and thanks to the interest of the Chief of the Weather Bureau it was promised that San Diego would be one of the first cities out of Washington to be equipped with such a structure. The architect of the plaza fountain (which was then unthought of) proffered his services to the government, and the park commissioners proceeded to lay out the plaza in harmony with the lines of the kiosk so as to give a fitting setting. The city authorities desired to have

the kiosk in the center of the plaza, but it was pointed out to them that such a location should be reserved for a fountain. In the spring of 1909, the kiosk was accepted by a city ordinance from the United States by the park commission, and on July 8 the recording instruments were started. While the plaza was being laid out Louis J. Wilde sauntered along one day, and when it was explained to him that the center of the plot was left vacant for an electric fountain he exclaimed: "Go ahead with the fountain—let it be the finest of its kind." The plaza fountain was the result, and it is the admiration of citizens and visitors alike. Thus the kiosk was father to the fountain.

THE KIOSK SHOWS THE WEATHER CONDITIONS ON THE STREET-LEVEL

The kiosk is a well-ventilated structure, designed to show accurate temperature, humidity, rainfall, and barometric conditions, and to display weather bulletins, charts, etc. The instruments are so arranged as to be in easy view of the passerby and yet retain their proper exposure. This is accomplished by having special thermometers made with bulbs projecting 12 inches to the center of the open air-space. In addition to a thermometer which continuously records the temperature for a period of two weeks, there are two mercurial thermometers showing extremes of temperature, etc. A hair-hygrometer shows the amount of moisture in the air in percentage of saturation, and the barometer the air-pressure. Perhaps the most ingenious of all the instruments is the rain-gage which admits the



Photographic copy of kiosk thermograph trace-sheets during a week in August, 1911, and a week in January, 1912

rain at the top of the kiosk. When rain enters the receiver, the water is conveyed to a double compartment bucket, each compartment holding exactly 0.01 of an inch. When one of the compartments fills it is overbalanced and in tipping actuates a hand which marks off the amount on a dial. A smaller hand shows the rainfall in inches. In the course of a day hundreds of persons stop in front of the kiosk and note the weather conditions. It is a matter of considerable satisfaction to the people that they are able to see the weather records in their making. The records are at the level of the "man on the street" a few feet above the sidewalk, exposed to summer sun, reflected heat of surrounding buildings, and the cold of settling air. The sole purpose of the kiosk thus is seen to be for the accommodation of the public. For official use or climatological purposes, forecasting, etc., it is necessary to have standardized weather records free from all local influences. To be compared with other stations of the Weather Bureau the official thermometers are exposed at an average of 100 feet elevation. This explains why Weather Bureau thermometers are always located in the free air. During periods of pronounced air-drainage, a difference in temperature of as many as ten degrees has been observed between the street and top of office buildings. While this may appear to be a considerable variation within a few hundred feet, yet there is probably twice this difference in temperature in various parts of the city. For example, at the bottoms of some of the cañons in San Diego County frost occurs twenty or thirty nights in the year. It will thus be seen that temperature is an extremely variable quan-

tity, and that the uses to which observations are to be put determine their significance, whether it is to collect climatic records for standardizing comparison, for the convenience of pedestrians, or for crops. By experiment it is possible to determine the average difference between surroundings and so secure what is termed a constant. For a series of observations extending over two years, the kiosk constant is about 6 degrees; that is, the kiosk shows the temperature averaging 3 degrees higher and 3 degrees lower than the official readings. During periods of unusual heat or cold, these variations have been doubled. On days of good ventilation, that is, when a moderate breeze is blowing, there is little difference between the street-level and the tops of buildings.

In addition to its function as an instrument shelter the kiosk displays in the other three windows weather bulletins, charts, etc. The western window is devoted to the marine meteorological work of the local station; the south window displays cloud charts and illustrations; and the east window contains a copy of all the publications of the local Weather Office. In addition to the seasonal weather data, the monthly summaries, the daily weather map, and the printed bulletins, a card index is maintained showing daily comparative weather conditions in San Diego for each day of the past forty years.

CHAPTER XXV

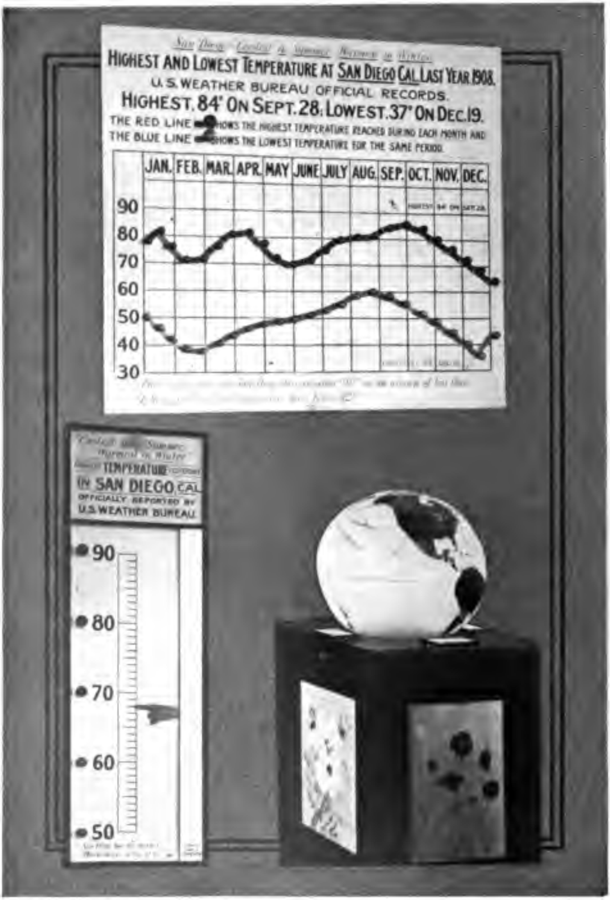
WEATHER EXHIBITS AT WORLD'S FAIRS*

IT is difficult to advertise a climate properly, for statistical tables, columns of figures and weather charts may be ever so carefully compiled and attractively labeled, but the general public balks at tables and charts. The Board of Supervisors of the county of San Diego, Cal., provided the necessary funds to prepare an attractive and practical method of showing features of the climate of San Diego at the Alaska-Yukon-Pacific Exposition at Seattle, Washington.

The San Diego climatic exhibit consists of three pieces of apparatus. To show the cool summers and the warm winters of San Diego an electric-flasher-board has been designed. This consists of a sign 7 feet high and 8 feet long, having vertical lines and horizontal divisions showing the months of the year and temperatures from 30 to 90 degrees. A row of red electric lights outlines the maximum temperature for every month of the year, and a row of blue electric lights the minimum temperature for a corresponding period. Beginning with January, the red lights burn consecutively, two lights for each month, until the whole year's monthly maximum temperatures are displayed. The illuminated trace requires about ten seconds to traverse the twelve months. These lights then disappear, and a line of blue lights is begun on the minimum portion of the board. When the line of blue lights is complete,

*Monthly Weather Review, Vol. XXXVII, pp. 176, 177.

Kiosk in San Diego Plaza, erected by direction of Willis L. Moore, Chief of United States Weather Bureau



The San Diego electrical climatic exhibit, Alaska-Yukon-Pacific Exposition, 1909. (Awarded Gold Medal.) Designed by Ford A. Carpenter.

showing the lowest point the thermometer touched each month, the red and blue lights are exhibited simultaneously for ten seconds. Immediately afterwards, the red line of lights again begins its trace over the sign, and is again followed by the blue line, and so on as long as the current lasts.

To show the current daily maximum temperature in San Diego during the summer of the exposition, there is a representation of a thermometer 7 feet high. Red lights serve to make each ten-degree point on its scale, and a movable hand, studded with small white lamps, points to the highest temperature at San Diego for the preceding day as officially reported by the local Weather Bureau office at Seattle.

The third piece of apparatus shows the cool summers and the warm winters of San Diego. The countries of the earth are outlined in color on the inside of a ground-glass globe twenty-four inches in diameter and illuminated by a lamp at its center. On the surface of the globe red and blue lights show the July and January positions respectively of the 50-, 60-, and 70-degree isotherms for the whole Northern Hemisphere. While most of the countries are labeled, there appears the name of but one city, that of San Diego. The globe is made to revolve slowly by a motor concealed in the base of the supporting cabinet. A careful study of this brilliantly illuminated globe shows the relation of San Diego's climate to that of other parts of the earth. The spectator at once sees that the courses of the summer isotherms between which San Diego lies, also inclose Alaska and Siberia, while the winter courses in blue embrace San Diego as well as portions of Arabia and Egypt.

It would seem practicable to apply some of these methods of attracting attention to more serious purposes than advertising. This would appear to be especially true of the illuminated and revolving globe. The boundaries of the countries of the world, the seas, the islands, and their designations are painted on the inside of the globe. Such a method allows complete isothermal and other lines, as well as the distribution of winds and rainfall, to be drawn in water-colors on the outside of the glass. Such drawings could be easily erased or changed.

That the general public is interested and studies such a climatic display was shown by the results of the preliminary display in one of the prominent store windows before shipment to Seattle. Several thousand people saw this exhibit during the three days it was shown in San Diego.

Note.—This exhibit was awarded a gold medal at the Seattle World's Fair. Although these pieces of apparatus were designed primarily for this fair, the exhibit has continued ever since, being on display at all of the large expositions and fairs throughout the United States for the past three years. At present this exhibit is being shown at the Los Angeles Chamber of Commerce, where it has been in operation during the intervals when no fairs or expositions were in progress.

CHAPTER XXVI

THE WEATHER BUREAU AND THE PUBLIC

A FEW years ago a member of the French Academy of Science called at the San Diego Weather Bureau office, and having been shown the meteorological apparatus and informed as to the application of the data to the everyday needs of commerce and agriculture, exclaimed, "You Americans are a wonderful people. You not only equal the French in the use of delicate instruments from which theories are evolved, but you excel us in making the results worth dollars and cents." And had this French scientist visited some of the Weather Bureau offices in the flood districts, or the cautionary signal stations on the Great Lakes, the Gulf of Mexico, or the Atlantic coast, he could have added human life to the pecuniary saving. An article in the Century Magazine a few years ago stated that the Weather Bureau costs the United States a million and a half dollars a year, but that a conservative insurance company figured that on an average the people of the United States saved annually $30,000,000 because of their weather service, and this in addition to thousands of lives.

THE CURVE OF COMFORT

The perfect adjustment of climate and health might be called the curve of comfort. It finds full expression in San Diego, and for that reason it is not strange that some people think the work of the

weather man is over when he hangs out his little card: "Fair tonight and Sunday."

It is believed that San Diego offers innumerable opportunities to show the ability of the Weather Bureau employes in perceiving and utilizing the service to the good of the community. Some of the practical uses of the Weather Bureau to the everyday walks of life may be found in the following quotation from the act of Congress of 1890, which summarizes the general functions of the Weather Bureau:

> *The Weather Bureau shall have charge of forecasting the weather; the issue of storm warnings, the display of weather and flood signals for the benefit of agriculture, commerce and navigation; the gaging and reporting of rivers; the maintenance and operation of seacoast telegraph lines and the collection and transmission of marine intelligence for the benefit of commerce and navigation; the reporting of temperature and rainfall conditions for the cotton interests; the display of frost, cold wave, and other signals; the distribution of meteorological information in the interest of agriculture and commerce, and the taking of such meteorological observations as may be necessary to establish and record the climatic conditions of the United States or are essential for the proper execution of the foregoing duties.*

Among the ways the San Diego office serves the public is the making and disseminating of weather, wind and temperature forecasts, issuance and display of storm warnings, and frost warnings; printing and distributing daily, monthly and annual bulletins, furnishing marine intelligence, the compilation of meteorological data; popularizing meteorology; supplying data to physicians and engineers; testing

meteorological instruments for local use, and in producing the records in courts of justice.

LOCAL FORECASTS ARE MADE AT 8 O'CLOCK

The San Diego Weather Bureau office receives every morning and evening, including Sundays and holidays, telegraphic weather reports from one hundred cities in the United States and Canada. These messages are entered on a large outline map of the United States, and after the wind direction, weather and precipitation are entered, lines are drawn connecting the stations with equal barometer and thermometer readings and the forecast for the ensuing thirty-six hours is made. The daily weather forecast is made from the morning report. Messages are received as early as seven o'clock, and such is the celerity made possible by the system used that with a force of only three employes the forecasts are distributed by telephone and telegraph, and type-printed bulletins, forecast cards and weather maps are mailed and posted before ten o'clock. In exceptional instances the published reports are on the streets within an hour after the last telegraphic report has been received. The forecasts are more widely distributed by the daily newspapers than by any other method. Next in value comes the display of the weather map in important localities about town. As the map is limited to an edition of 125 copies, it is a rule of the office that it must be posted so that not less than twenty-five people see it. In addition, the office printing press turns out several hundred bulletins and forecast cards which are mailed regularly to interested persons. The quickest

method of disseminating the weather forecast is by telephone. Any person having access to a telephone may obtain the weather forecast by requesting it of "information," to whom it is given at nine o'clock every day. Special forecasts may be obtained any time at the local office. During threatening weather the four telephones in the office are kept busy answering calls. On one threatening morning the calls were so frequent that a tally was kept, showing that between the hours of nine and twelve 179 inquiries had been answered. Telephone inquiries are never discouraged; on the contrary, the public is invited to call up the Weather Bureau office at any time for any weather information they may wish.

HOW THE FORECASTS ARE USED

The utilization of the forecasts by the public covers a wide range. A few of the uses are as follows: Protecting the raisin crop when the grapes are drying on the ground in the autumn, the cutting of hay so as to save loss by showers, and also protection of cattle from sudden snowstorms in the mountain meadows in the autumn and winter. The irrigation of citrus orchards is governed by the forecasts, for aside from waste of water, considerable damage results if rain follows a generous irrigation. The stages and automobile parties rely on the reports of the bureau as to the condition of roads, etc., in the back country. Other occupations affected are building operations throughout the year, and the protection of perishable goods on open wharves and docks. Special temperature forecasts are used by

ice and cold-storage companies. Shipments of lemons are governed largely by the special shippers' forecasts of probable temperature conditions on interior railroad points. Frost warnings have been successfully used when smudging and heating the orange groves is necessary. Florists growing tropical flowers in the open are also warned of dangerous temperatures. Wind forecasts are utilized by the fishing fleet and small craft in the harbor and by tourists in making excursions to neighboring islands. Yachting and racing boats use wind forecasts in preparing for special events.

Signals are displayed on the Point Loma wireless masts, on the top of the Spreckels Brothers' coal bunkers, and on the boat-house at Coronado beach. Shippers claim that since the establishment of this station San Diego has never experienced high winds without storm flags having been flying for several hours. Although more than half of the time the signals have been displayed no winds of consequence have occurred locally, the signals are sometimes hoisted for the use of shipmasters sailing to other ports.

WIRELESS WEATHER WARNINGS

The marine interests in San Diego claim that the Weather Bureau is of no little value to them in addition to the usual storm signal service. Every deep-water vessel entering the port of San Diego is supplied on arrival with weather and wind charts, and on their departure with copies of the daily weather map and ocean meteorological charts covering their outward course. Through the splendid

coöperation of the wireless operators of the United States navy this service has been extended to include ships within the wireless radius of the Point Loma station. Not long ago a foreign vessel, over a hundred miles at sea, asked for weather conditions over the proposed course. A forecast map was hastily constructed by the aid of their own and coast observations, and a forecast issued to them in a few minutes. When the naval fleet is in southern waters, this office keeps the admiral informed daily by wireless of existing and probable weather conditions.

THE WEATHER MAN'S WORK BEGINS EARLY

The work of the local Weather Office begins at 4.40 A.M. when the first observation of the day is made. Shortly after this hour the simultaneous observations begin coming in by telegraph. Observations are also made at noon, and at 4.40 P.M. The office is open until the last telegraphic report is received and the evening weather map is completed, which is usually about seven o'clock.

Some indirect instruction in meteorology is given, but of necessity to a limited extent. It has been found that the best medium of popular meteorological information is the kiosk in the plaza; as a means of popularizing meteorology it has no equal. Other instruction includes visits at the local Weather Office from the physical geography classes of the normal school and cadets from training ships. Explanatory wind and pressure charts and data are furnished to the aviation school on North Island.

Composite telephotograph of strato-cumulus clouds over the northern portion of San Diego Bay
Photographed from the eucalyptus grove of the California-Panama Exposition in Balboa Park

CHAPTER XXVII

THE CLIMATE SUMMARIZED IN FIVE PARAGRAPHS

FOR sixteen years the writer has been in charge of the local office of the United States Weather Bureau in San Diego, and the intimate acquaintance thus formed with the climate emboldens him to summarize the cardinal features in the five following paragraphs treating on the temperature, rainfall, wind, sunshine, and comparative seasonal temperatures:

Temperature.—Since the beginning of meteorological records, the temperature has averaged less than one hour per year above 90°. Highest and lowest temperatures ever recorded are 101° and 32°. The thermometer has never gone below 32°, and no snow has ever fallen, although the records extend back to 1871.

Rainfall.—The annual rainfall averages ten inches. Back from the coast, the rainfall increases to over forty inches. It is in this well-watered region that the magnificent water-supply of San Diego is located.

Wind.—The sea breeze keeps San Diego cool in summer and warm in winter, and the nearby mountains and desert give it a dry marine climate. The wind averages five miles per hour throughout the year.

Sunshine.—The sun shines in San Diego on an average of 356 days a year. The photographic sunshine recorder shows that for over twenty years

there has been an average of less than nine days a year without one hour or more of sunshine.

Comparative Seasonal Temperatures.—Temperatures are usually shown on a globe by lines which pass through regions of the same degree of heat or cold. Red lines of 60° and 70°, showing the summer temperatures at San Diego, also enclose Alaska and Siberia. Blue lines of 50° and 60°, showing the winter temperature at San Diego, enclose Egypt and Arabia. Thus San Diego may be said to have Alaskan summers and Egyptian winters.

NOTE.—After these pages were printed occurred the great California freeze on January sixth and seventh, nineteen thirteen. The temperature at San Diego was lower than 32° for twelve hours, reaching the absolute minimum of 25° at six A.M., January seventh.

TABLE XIV.—*Comparative Meteorological Data Since 1872*

Month	Temperature						Precipitation		
	Highest	Year	Day	Lowest	Year	Day	24-hr. maximum	Year	Day
January	83	1904	13	32	1880	31	2.49	1882	12
February	85	1889	12	34	1891	10	2.39	1901	8-9
March	99	1879	29	36	1894	5	2.40	1906	24-25
April	96	1910	23	39	1875	7	1.20	1886	11-12
May	98	1896	25	45	1883	2	1.45	1884	14-15
June	94	1877	10	50	1884	14	.25	1899	1
July	93	1911	14	54	1880	4	.83	1902	24-25
August	93	1909	30	54	1879	29	1.80	1873	12
September	101	1883	22	50	1880	29	.37	1890	28-29
October	96	1901	21	44	1878	30	1.82	1883	27
November	93	1904	8	38	1881	18	2.75	1879	9
December	82	1874	6	32	1879	25	2.52	1873	4

Month	Wind				Relative Humidity		Sunshine		
	Max. Vel.	Dir.	Year	Day	A.M.	P.M.	No. of Hrs.	Possible	Per-Cent Poss.
January	37	....	1873	..	73	69	218	318	68
February	40	SE	1878	13	78	68	211	320	67
March	43	SE	1912	9	80	68	242	372	64
April	39	....	1877	..	82	68	270	390	69
May	33	S	1905	7	82	72	247	430	57
June	24	SW	1886	11	85	72	253	428	60
July	30	NW	1881	2	87	74	292	437	67
August	25	SW	1900	3	86	73	297	414	71
September	28	NW	1881	7	84	72	271	371	73
October	32	NW	1877	29	80	73	256	352	73
November	33	W	1905	27	72	70	238	314	76
December	38	W	1906	31	68	67	233	311	74

Table XV.—*Meteorological Summary of San Diego, California, for 1911*

MONTH 1911	TEMPERATURE, in Degrees Fahr.									
	Mean	Departure from Normal	Mean		Mean		Greatest Daily Range	Absolute		
			High	Low	Daily Change	Daily Range		High	Low	Range
January	56.2	*2.2	63.5	48.9	3	15	26	77	41	36
February	52.2	-2.4	59.1	45.4	2	14	26	70	34	36
March	58.0	*1.8	63.8	52.3	2	12	23	77	44	33
April	57.7	-0.5	63.2	52.2	1	11	29	79	44	35
May	59.3	-1.5	64.3	54.3	1	10	22	74	49	25
June	62.4	-1.4	67.2	57.5	2	10	32	91	53	38
July	66.2	-0.7	71.1	61.2	2	10	30	93	59	34
August	67.4	-1.3	72.8	62.1	2	11	18	84	58	26
September	66.2	-0.7	72.3	60.1	2	12	19	76	54	22
October	63.0	0	70.6	55.4	2	15	28	84	50	34
November	61.7	*2.7	70.5	52.9	3	18	33	82	44	38
December	53.4	-2.3	61.9	45.0	2	17	24	78	36	42
Mean	60.3	-0.3	66.7	53.9	2	13	26	93 **	34 †	42 ‡

*Excess. **July 14. †February 16. ‡December.

MONTH 1911	RAINFALL									
	Night 5 p.m. to 5 a.m.	Day, 5 a.m. to 5 p.m.	Total Midnight to Midnight	Departure from Normal	Greatest in 24 hours		Number of Days With			
					Amt.	Date	.01 or More	.04 or More	.25 or More	1.00 or More
January	1.59	1.76	3.35	*1.35	2.17	9–10	9	8	4	1
February	3.84	3.08	4.92	*2.96	1.69	27–28	11	11	5	2
March	.45	.47	.92	- .78	.37	3	7	5	2	0
April	.33	.32	.65	- .09	.36	1–2	5	4	1	0
May	.00	.01	.01	- .40	.01	5	1	0	0	0
June	.01	.00	.01	- .02	.01	20	1	0	0	0
July	.03	.09	.12	* .12	.05	10	4	2	0	0
August	.00	.00	.00	.00	.0	....	0	0	0	0
September	.01	.09	.10	* .04	.09	30	2	1	0	0
October	.27	.01	.28	- .18	.28	26–27	2	2	0	0
November	.02	.00	.02	- .81	.02	10	1	0	0	0
December	.58	.81	1.39	- .43	.56	20	8	7	3	0
Mean	5.13	6.64	11.77	*1.76	2.17	Jan. 9-10	51	40	15	3

*Excess.

TABLE XV—*Meteorological Summary of San Diego, California, for 1911, continued*

MONTH 1911	WEATHER								
	Sunshine	Av. Cloudin's Scale of 10	Number of Days			Number of Days			
	%		Clear	Partly Cloudy	Cloudy	Fog	Hail	Frost	Thund'r-storms
January	54	4.7	15	5	11	4	0	0	0
February	63	4.0	13	8	7	1	1	1	0
March	56	4.5	14	9	8	1	0	0	0
April	62	3.7	16	10	4	0	0	0	0
May	67	3.3	20	8	3	2	0	0	0
June	55	4.6	13	11	6	1	0	0	0
July	57	4.4	15	12	4	3	0	0	3
August	78	2.0	28	3	0	3	0	0	0
September	76	2.5	25	2	3	6	0	0	0
October	82	1.9	23	8	0	5	0	0	0
November	79	2.0	22	7	1	0	0	1	0
December	79	2.2	21	8	2	0	1	6	2
Mean	67	3.3	225	91	49	26	2	8	5

MONTH 1911	WIND						Air and Sea Temperature in Harbor at 12 Noon Local Time, 1910			
	Total Movement Miles	Prevailing Direction	Average Hourly Velocity (Miles)	Maximum Velocity			Average		Extremes	
									Water	
				Miles an hour	Direction	Date	Air	Water	Highest	Lowest
January	3661	NE	4.9	21	S	10	58	55	56	54
February	4365	E	6.5	26	W	25	59	56	57	55
March	4179	NW	5.6	26	S	3	61	61	63	57
April	4502	NW	6.3	23	S	6	66	66	69	63
May	4874	NW	6.6	21	NW	21	64	69	70	67
June	4811	NW	6.7	23	NW	5	64	69	70	68
July	4620	NW	6.2	26	NW	14	70	72	72	71
August	4446	NW	6.0	22	NW	15	71	72	74	71
September	4565	NW	6.3	23	NW	24	71	73	75	70
October	3876	NW	5.2	21	NW	2	69	67	71	64
November	3907	NE	5.4	19	NW	22	64	64	66	61
December	4343	NE	5.8	26	NW	17	62	58	60	56
Mean	52149	NW	6.0	26	W	*25	64.8	65.2	75	54

*Feb. 25.

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ADDENDA

In order to bring the meteorological tables in this volume down to date, the following addenda has been prepared from the records of the U. S. Weather Bureau to include the year ending June 30, 1922.

AVERAGE NUMBER OF DAYS

______________TO 1922

MONTH	Clear	Partly Cloudy	Cloudy	With 0.01 Inch Rain	With 0.25 Inch Rain	With Dense Fog
January....	16	8	7	7	3	2
February...	14	8	6	7	3	2
March.....	14	9	8	7	2	1
April.......	15	9	6	4	1	2
May.......	12	10	9	3	0	0
June.......	14	11	5	1	0	1
July.......	17	11	3	0	0	1
August.....	19	9	3	1	0	1
September..	19	8	3	1	0	2
October....	18	9	4	3	0	4
November..	18	7	5	4	1	3
December..	18	7	6	6	2	1
Annual...	194	106	65	44	12	20

TABLE VII—*Monthly, Seasonal and Annual Rainfall at San Diego, California.* (*Elevation, 93 feet.*)

Season	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Seasonal	Year	Annual
1912	...	...	...	...	...	...	...	...	...	...	...	...	...	1912	10.56
1912–13	0.14	0.26	0	0.89	0.40	0.03	1.19	2.40	0.42	0.08	0.07	0.09	5.97	1913	7.30
1913–14	0.06	0.02	0.02	T	2.23	0.72	3.59	1.90	0.36	0.85	0.08	0.00	9.83	1914	10.90
1914–15	0.00	0.00	T	1.05	0.86	2.21	4.91	3.62	0.33	1.15	0.28	T	14.41	1915	13.62
1915–16	T	0.00	T	0.00	0.73	2.60	7.56	0.66	0.98	0.01	0.01	T	12.55	1916	11.56
1916–17	0.02	0.01	0.25	0.87	0.05	1.14	4.32	1.84	0.26	1.06	0.31	T	10.13	1917	8.04
1917–18	T	T	T	0.17	0.08	T	1.64	1.52	4.57	T	T	0.06	8.04	1918	11.99
1918–19	T	0.11	0.08	0.42	1.91	1.68	0.61	1.46	1.83	0.30	0.34	0.00	8.74	1919	6.76
1919–20	T	0.01	0.26	1.04	0.43	0.48	0.43	2.87	2.46	0.47	0.44	0.02	8.91	1920	7.69
1920–21	T	0.01	0.08	0.18	0.19	0.54	2.02	0.35	1.13	0.04	2.54	T	7.08	1921	17.55
1921–22	T	T	1.24	0.67	0.30	9.26	3.45	1.86	1.34	0.17	0.36	T	18.65	1922	...
Means (for 72 Years)	0.06	0.10	0.10	0.37	0.92	1.84	1.93	1.92	1.50	0.60	0.34	0.06	9.74	...	9.71

NOTE—For the years 1850 to 1912 of this table see pages 36 and 37.

Table VIII—*Showing Highest and Lowest Temperatures Registered During Each Month from January, 1913, to June, 30, 1922, at San Diego, California.*

Year	Jan.		Feb.		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1913.......	78	25	73	40	76	42	81	44	68	47	79	56
1914.......	76	42	78	43	88	48	85	50	69	50	79	55
1915.......	69	38	75	42	84	42	74	46	84	45	77	57
1916.......	65	36	78	38	81	43	79	48	72	50	74	52
1917.......	77	40	75	41	75	39	79	44	50	87	87	54
1918.......	69	39	74	40	80	44	84	47	73	49	82	56
1919.......	77	35	67	41	71	40	76	49	68	54	91	57
1920.......	76	37	76	42	77	41	77	45	77	50	71	57
1921.......	76	38	89	39	74	46	88	44	65	49	79	54
1922.......	72	35	72	37	73	38	80	44	81	48	77	55

Table VIII—*Showing Highest and Lowest Temperatures Registered During each month from July, 1912, to June, 30, 1922, at San Diego, California, continued.*

Year	July		August		Sept.		October		Nov.		Dec.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1912.......	85	58	79	56	86	54	94	49	86	45	78	39
1913.......	78	60	85	59	110	57	86	53	82	48	72	43
1914.......	73	60	78	60	78	54	90	54	89	47	70	39
1915.......	82	56	91	60	77	56	80	52	81	42	76	40
1916.......	74	58	84	58	80	56	78	46	74	39	76	38
1917.......	78	61	78	60	92	58	81	48	85	46	78	44
1918.......	79	61	82	59	94	57	90	54	82	42	78	35
1919.......	79	60	78	60	79	57	83	46	82	36	84	42
1920.......	78	58	82	59	78	52	77	45	74	46	72	40
1921.......	77	59	81	60	89	55	87	50	93	45	79	46
1922.......	..	..	..	..	..	..	..	..	..	..	..	..

Note—For the years 1872 to 1912 of this table see pages 38 and 39.

TABLE XIV—*Comparative Meteorological Data, 1872 to 1922, San Diego, California.*

Month	Temperature						Precipitation		
	High-est	Year	Day	Low-est	Year	Day	24 hr. maxi-mum	Year	Day
January	83	1904	13	25	1913	7	2.49	1882	12
February	89	1921	24	34	1891	10	2.39	1901	8–9
March	99	1879	29	36	1894	5	2.40	1906	24–25
April	96	1910	23	39	1875	7	1.20	1886	11–12
May	98	1896	25	45	1915	2	1.45	1884	14–15
June	94	1877	10	50	1884	14	.25	1899	1
July	93	1911	14	54	1884	4	.83	1902	24–25
August	93	1909	30	54	1879	29	1.80	1873	12
September	110	1913	17	50	1880	29	1.50	1920	30–1
October	96	1901	21	44	1878	30	1.82	1883	27
November	93	1904	8	36	1919	28	2.75	1879	9
December	84	1919	28	32	1879	25	3.00	1921	25–26

Month	Wind				Relative Humidity		Sunshine		
	Max. Vel.	Dir.	Year	Day	A.M.	P.M.	No. of Hrs.	Pos-sible	Per-Cent Poss.
January	54	S	1916	27	73	69	211	318	66
February	45	S	1914	20	79	69	209	320	65
March	46	W	1916	23	80	68	246	372	66
April	46	W	1915	30	82	68	269	390	69
May	33	S	1905	7	82	72	252	430	59
June	30	S	1918	10	86	73	258	428	60
July	30	NW	1881	2	88	74	293	437	67
August	25	SW	1900	3	87	74	299	414	72
September	28	NW	1881	7	85	73	271	371	73
October	32	NW	1877	29	81	72	257	352	73
November	34	W	1919	7	71	69	240	314	76
December	40	W	1916	25	68	67	232	311	74

NOTE—See Page 113.

Carpenter, Ford A.

The climate and weather of San Diego, California. 1913.